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BOTANICAL GAZETTE

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A MORPHOLOGICAL STUDY OF THUJA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XXXIX.

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(WITH PLATES VI–VIII)

MATERIAL for the study of *Thuja occidentalis* L. was collected in the vicinity of Chicago during the late spring and early summer of 1901. A few collections were made in June 1902, in order to determine whether the time of fertilization varies in two successive seasons. The trees were visited twice each week and material fixed immediately after the removal of the branches. Branches were also kept in the laboratory, some having water pressure applied to the cut end of the stem, and collections were made daily. All the material from which illustrations are made was taken from a single tree, the most vigorous one to be found. Collections were made from many other trees in order to determine whether the periods of the various stages of development are the same in different individuals of the same locality. Little difference could be observed.

For stages before the formation of archegonium initials 1 per cent. chromo-acetic acid was most useful, but for later stages it was not so good, as it was not possible to secure rapid penetration of the tissues even when used at a temperature of 80°. A modification of Carnoy's formula was found to give the best results for fertilization and succeeding stages, although many fixing agents were given a thorough trial. None of the fixing

agents proved entirely satisfactory. Flemming's triple stain gave good results for pollen tubes and early stages in the development of the archegonia, but by far the most satisfactory stain was Haidenhain's iron alum-haematoxylin. Delafield's haematoxylin combined with orange G was best for embryos. Sections were cut 3 to 5 μ thick.

THE POLLEN GRAIN AND POLLEN TUBE.

No attention was given to the formation of microspores from the mother cell, their study being taken up shortly after the separation of the tetrads (*fig. 1*). The appearance of the pollen grains at the time of shedding is shown in *fig. 2*. It does not appear that prothallial cells are cut off. Methods which easily demonstrate the prothallial cells of Pinus and similar forms have failed to show any such structures in Thuja. However, considering the ephemeral nature of prothallial cells in most gymnosperms, and the small size of the microspores of Thuja (20 μ in diameter), it is possible, though not probable, that they may have been overlooked. So far as could be determined, the next step after the separation of the tetrads is the organization of a tube nucleus and a generative cell (*fig. 2*). The microspores of *Cupressus Benthamiana* and of *Biota orientalis* seem in every respect like those of *Thuja occidentalis*.

In material collected June 2, 1901, the pollen tube had penetrated a short distance into the nucellus (*figs. 3–4*). The generative cell had already divided, and both the tube and stalk nuclei were in advance, and close against the large body cell. One of these nuclei is invariably somewhat smaller than the other. In *fig. 4* the smaller nucleus is not shown, as it lies immediately beneath the larger one. Conspicuous protoplasmic streams radiate from the tube and stalk nuclei downward to the end of the pollen tube, but little cytoplasm is found above the body cell. The nucleus of the body cell is in general spherical and is surrounded by a thick sheath of cytoplasm (*figs. 4–5*). A deeply staining spot, presumably kinoplasmic in nature, lies in the cytoplasm. Strasburger (11) shows this spot in his

figures of Juniperus, and Chamberlain shows similar structures associated with the male nuclei of *Pinus Laricio*. The finely granular areas in the body cell of Pinus, as described by Miss Ferguson (**8**), and the kinoplasmic regions described by Coker (**5**) for the egg of Podocarpus seem to consist of the same substance. The spots, though generally present in the body cell, were not found in the male cells of Thuja. These structures are suggestive of the blepharoplasts of Ginkgo and certain cycads, and may be a survival of some such structures possessed by ancestors from which the Pinaceae have descended.

Before the appearance of the archegonium initials (June 16, 1901), the penetration of the pollen tube is relatively slow, but at this time its downward movement is much accelerated. The tube quickly pierces the remaining rows of nucellar cells, spreads itself over the mouth of the archegonium complex, and absorbs almost entirely the remnants of the neck cells, thus laying bare the upper ends of the eggs (*fig. 10*). The body cell elongates (*fig. 5*) and divides into two hemispherical cells of the same size, this division taking place immediately before fertilization. That both cells are functional is shown by the fact that when only one pollen tube enters the complex two embryos are formed. In many instances it was observed that the contents of the pollen tube, which was in advance of the others, had fertilized two eggs. The equal size of the male cells is another evidence that both are functional.

Arnoldi (**1**) finds in Cephalotaxus the two male cells of the same size. Strasburger and also Belajeff (**3**) figure the male cells of Juniperus as equal. Arnoldi's (**2**) figures of the male cells of Sequoia show them to be equal. According to Coulter (**6**) the male cells of *Pinus Banksiana* are alike in size and volume. Chamberlain (**4**) finds the same to be true of *Pinus Laricio*. In cycads male cells are equal. Belajeff (**3**) observed that in Taxus one of the male cells is much smaller than the other and does not enter the egg at all. Coker (**5**) finds one functioning male cell in Podocarpus. In *Pinus Strobus* Miss Ferguson (**8**) reports them as unequal, with the larger cell invariably in advance.

There can hardly be any doubt that the occurrence of two equal male cells is more primitive, and that any difference in size or loss of function is a more specialized condition. It seems reasonable to suppose that both male cells are functional in all forms which have archegonia collected in a complex, for there is nothing to prevent each male cell from reaching an egg. In forms where the male cells are unequal in size the archegonia are scattered, thus making it practically impossible for the second male cell to function, and this will of course account for the reduced size.

Three to four pollen tubes appear to be the normal number in Thuja. They either pursue different routes through the nucellus or pass down side by side. In the latter case, one has its tip in advance of the others. In numerous instances it was observed that when the eggs fail to function, as they frequently do, the pollen tube penetrates to the bottom of the complex and in some instances pierces the jacket cells. When this occurs the male cells increase very much in size as the tube nears the bottom of the archegonium complex (*fig. 7*). In one instance the cells were 50 μ in length. The longer diameter of the hemispherical male cell at the time of fertilization is in general 20 μ.

DEVELOPMENT OF THE ARCHEGONIUM.

Early stages in the development of the endosperm were not studied, but the process seems to be similar to that described by Jäger (9) for Taxus.

The archegonium initials are differentiated about the middle of June, their number being usually six. They rapidly elongate, become conical, and as yet have very little cytoplasm (*fig. 8*). The nuclei move toward the outer end of the initials and the neck cells are cut off (*fig. 9*). So far as could be determined they are cut off simultaneously. Each neck cell divides by anticlinal walls, forming from two to six cells, and there is no periclinal division. Almost immediately after the last anticlinal wall is formed the neck cells begin to disorganize, and they are soon almost entirely assimilated by the central cells, which at this time are increasing in volume at a very rapid rate.

About the time of the cutting off of the neck cells, the jacket cells appear. At first they are poor in contents, but soon become filled with dense cytoplasm, and the adjacent layer of prothallial cells also shows a marked increase in activity. Protoplasmic connections between the jacket cells and the central cells were not seen, but it is possible that they were overlooked owing to the extreme thinness of the dividing wall. It is not believed that the nuclei of the jacket cells pass into the central cells, as reported in Cephalotaxus by Arnoldi (1).

Shortly after fertilization the jacket cells break down, and in many cells the chromosomes become separated, and are then in a favorable condition for counting, the gametophyte number being twelve.

After the neck cell has been cut off, the nucleus of the central cell lies very close to the upper end of the cell (*fig. 10*) and enlarges so much that its longer diameter is sometimes more than four-fifths of the diameter of the egg. A large vacuole (*figs. 10–11*) now rounds out in the center of the cell. Cytoplasmic masses collect at each end of the central cell, and are connected with each other by a thin layer at the periphery of the central cell. Two deeply staining masses, presumably kinoplasmic in nature, are present. The one near the nucleus resembles somewhat the mass mentioned in connection with the body cell, but it is not so sharply limited. The other, in the lower end of the egg, sometimes stains so densely that it often resembles an overstained nucleus.

At this stage the tip of the pollen tube is in the mouth of the archegonium complex, and is separated from the central cells by remnants of the neck cells.

THE VENTRAL NUCLEUS.

Karyokinetic figures showing the cutting off of the ventral nucleus were obtained in material fixed June 20, 1901, and June 16, 1902 (*fig. 12*). It takes a position at one side of and a little above the egg nucleus, almost in contact with the wall of the egg, and usually on the side nearest the center of the arche-

gonium complex. It is not separated from the egg by a wall, but lies free in the cytoplasm of the egg. The figures of Strasburger (11) and Belajeff (3) show that it takes a similar position in Juniperus.

Arnoldi (2) claims that there is no ventral canal cell in the Cupresseae, and among the Taxodieae he failed to find it in Cunninghamia, Sequoia, Cryptomeria, and Taxodium. Coker (5), however, finds a ventral nucleus in Taxodium, although it is not separated from the egg by a wall, lying free in the cytoplasm of the egg. He also finds the ventral nucleus very prominent in Podocarpus, but here also no wall is formed. Strasburger (11) as long ago as 1879 figured the spindle in Juniperus. There can be no doubt that the free ventral nucleus without a separating wall is a specialized condition. A similar reduction in the neck canal cells can be seen as one traces a series through the bryophytes and pteridophytes. In most of bryophytes the number of neck canal cells is rather large; in the pteridophytes the number has become small, often only two, and even here a wall seldom forms between the two nuclei. In most gymnosperms there is a definite ventral canal cell, cut off by a conspicuous wall; in Taxodium, Podocarpus, and Thuja the nucleus is formed, but the wall is suppressed. This may be the case in the forms described by Arnoldi (1, 2), and may have led him to think that the ventral canal cell was not represented. We doubt whether a ventral canal cell is lacking in any gymnosperm, and believe that the absence of such a cell, or at least a nucleus representing it, could be established only by the most indubitable evidence.

When an archegonium has not been fertilized, there are indications that the ventral nucleus divides (*fig. 13*). Coker (5) holds that in Podocarpus these divisions are amitotic. In Thuja after fertilization there are frequent instances of a further division of the ventral nucleus, and these divisions are mitotic. Coulter and Chamberlain (7) suggest that in some cases the ventral nucleus in Pinus may be fertilized instead of the egg. A number of the writer's preparations of Thuja lead him to believe that both the ventral nucleus and the egg in the same archego-

nium may be fertilized. In *fig. 17* the proembryo is well advanced, while the ventral nucleus has formed a group of four cells — three of which are shown in the figure, as it was drawn from a single section — which certainly suggests a proembryo in the four-celled stage. Another preparation shows eight cells with indications that walls are soon to appear. The probability of such a fertilization is strengthened by finding occasionally in the same ovule embryos growing upward into the nucellus (*fig. 27*), as well as downward into the endosperm. These embryos are so old that it was not possible to determine definitely if their suspensors are connected with a common archegonium, but such appears to be the case. The embryos growing upward into the nucellus are not so vigorous as those growing downward into the endosperm.

FERTILIZATION.

The contents of the pollen tube are discharged into the space immediately above the archegonium complex, but it does not appear that very much enters the egg. Traces of the cytoplasmic contents of the pollen tube can usually be seen in the upper end of the egg, usually showing as densely staining masses. In some cases the tube and stalk nuclei enter the egg, in others only one of these nuclei enters, but in the great majority of cases they do not enter the cytoplasm of the egg at all, but disorganize in the space above the archegonia. *Fig. 14* shows the male cell entering the egg. At this stage, in general, the large vacuole which occupied the center of the egg has disappeared, and the egg nucleus has taken its place. Soon after coming in contact with the egg the male nucleus slips from its sheath and moves downward toward the egg nucleus. The actual breaking out of the male nucleus from its cytoplasmic sheath was not observed, but numerous preparations showed remnants of the sheath in the upper end of the egg. *Fig. 15* shows the male cell just after its escape from the sheath, and also shows one of the rare cases in which the large vacuole is still present at this stage. The male nucleus passes down, and

on coming in contact with the egg nucleus presses the side of the latter inward (*fig. 16*), and finally fuses with it. A close series of stages covering the period from the escape of the male nucleus from its sheath to final fusion was not secured. The time from the rupture of the pollen tube to the formation of the fusion nucleus is very short. Ovules taken on June 20, 1901, from a twig bearing perhaps a dozen cones, showed all stages from the formation of ventral nuclei to well developed suspensors. Not infrequently a male cell in contact with the tip of an egg, and proembryos of four cells may be found in the same complex.

THE PROEMBRYO.

The fusion nucleus is in general below the center of the egg, and remains in this position until the first division is completed. The dividing nucleus is surrounded by a mass of deeply staining cytoplasm (*fig. 18*), which as the spindle disappears closes in between the two nuclei and envelops them, as shown in *fig. 19*. The spindle, as in the first division of the egg in other gymnosperms, is intranuclear. When the two nuclei are in the stages shown in *figs. 19–20*, the cytoplasm above begins to thin out, showing in many instances a vacuole-like space between the ventral nucleus and the proembryo. This space is never entirely free from cytoplasmic masses. In some preparations, as well as in all later stages, it appears more like a break in the continuity of the cytoplasm than like a vacuole (*figs. 22–23*).

The two nuclei sink to the bottom of the egg, lose their rounded form (*fig. 20*), and divide simultaneously (*fig 21*); while the ventral nucleus has enlarged considerably (*figs. 22–23*) and is quite conspicuous.

The four nuclei resulting from the second division of the proembryo usually arrange themselves in pairs, as shown in *fig. 22*, which is reconstructed from serial sections. The third division of the proembryo is also simultaneous (*fig. 23*), and gives rise to eight free nuclei, and walls appear shortly after this last division. Among the cycads and in Ginkgo, after fertilization, there is a long period of free nuclear division before any

walls are formed. In Podocarpus sixteen or thirty-two free nuclei are formed; and in Taxus and Cephalotaxus a like number. In Thuja the number of free nuclei is constantly eight, while in Pinus and its allies the number is only four. Even so small a number as two is reported by Strasburger (**11**) as occasionally occurring in Ephedra; and in Gnetum, according to Lotsy (**10**), there is no free nuclear division at all. It would seem that there is a gradual transition from an extensive free nuclear division to a condition in which the first division of the egg is followed immediately by the formation of a wall. In the development of the embryo Thuja has not advanced so far as forms like Pinus, although in its cyclic arrangement and in the reduction of the male gametophyte it has proceeded much further.

A wall transverse to the long axis of the oospore now separates the eight nuclei into two groups, each group having four nuclei. The nuclei of the lower group are completely walled in, and from these the embryo develops. Walls parallel to the long axis of the oospore extend from the transverse wall upward a short distance into the cytoplasm of the oospore, thus walling in the nuclei on three sides, but leaving them freely exposed to the cytoplasm above (*fig. 24*). The ventral nucleus is still visible but shows marked signs of disintegration.

The four nuclei of the upper group now divide simultaneously, and walls are formed transverse to the long axis of the archegonium (*figs. 24–25*). The proembryo at this time consists of twelve cells; two tiers of four cells each, and the group of four in the tip, which were formed at the time shown in *fig. 23*. The upper tier of incompletely walled nuclei, produced by the division shown in *fig. 24*, soon disintegrate. The second tier rapidly elongates and forms the four suspensors (*fig. 26*).

A single embryo is developed from the lowest group of cells, which is thrust downward by the suspensors. In the Abieteae each cell forms an embryo. Coulter (**6**) has shown that in *Pinus Laricio* two embryos may develop at the end of a single suspensor. In Thuja there is a tendency to form two groups of cells. The line of division is clearly apparent in the earlier

stages of the embryo, especially in cross sections (*fig. 28*). The line of division disappears as the embryo becomes older.

My acknowledgments are due to Professor John M. Coulter, and Dr. Charles J. Chamberlain for assistance rendered during the progress of the work.

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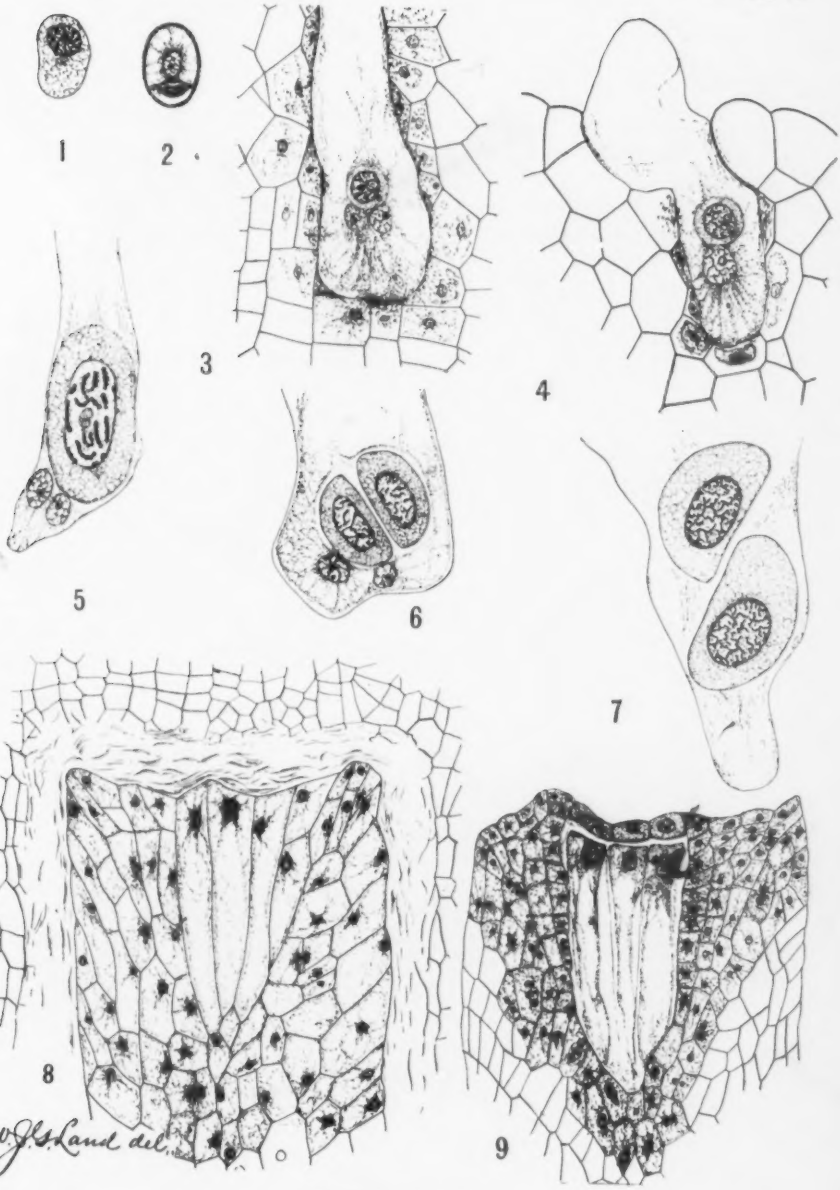
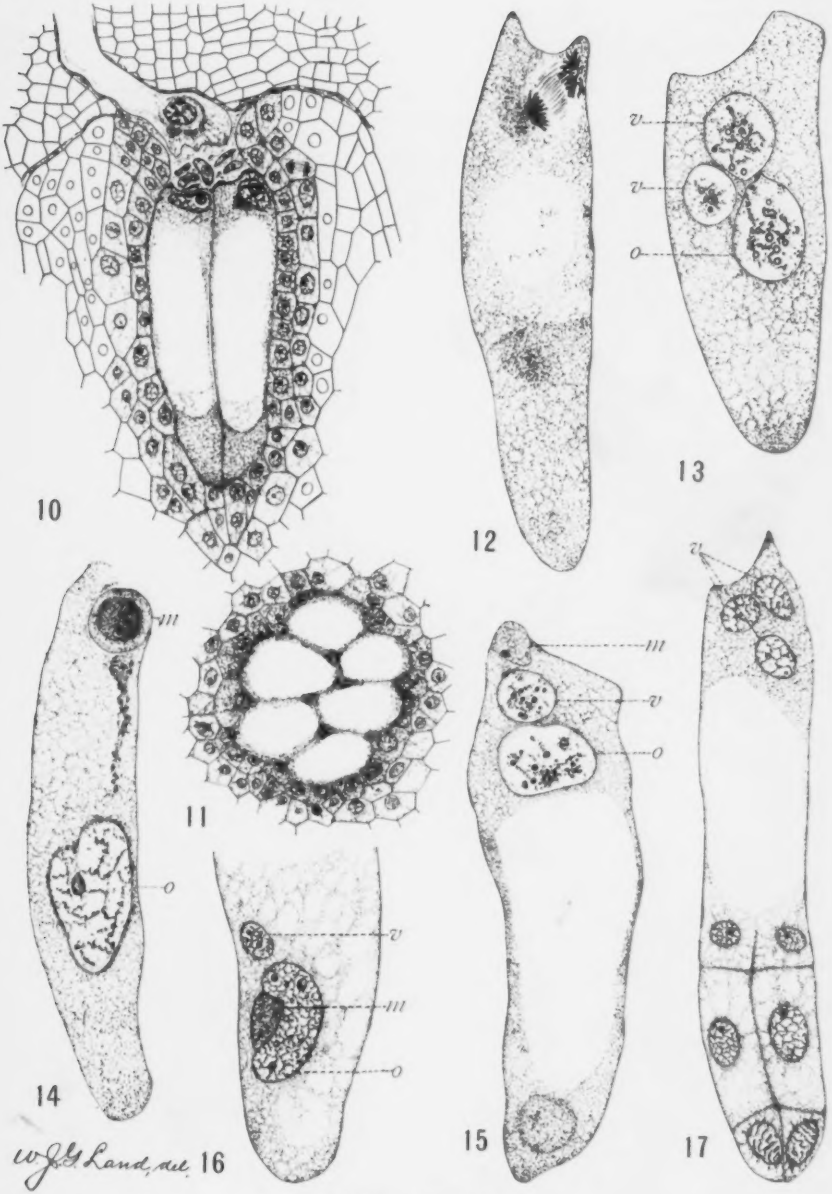
EXPLANATION OF PLATES VI–VIII.

The figures, with the exception of *figs. 8, 9, 10, 11*, and *28*, were drawn with Abbé camera lucida, Bausch and Lomb $\frac{1}{12}$ objective and ocular 2. For *figs. 8, 9, 10, 11*, and *28* a Bausch and Lomb $\frac{1}{8}$ objective and ocular 2 were used. The magnification of *figs. 8, 9, 10, 11*, and *28* was 450; all others 850. The plates are reduced to one-half the original size. The abbreviations used are: *b*, body cell; *v*, ventral nucleus; *m*, male cell; *o*, egg nucleus; *s*, suspensor



LAND on THUJA



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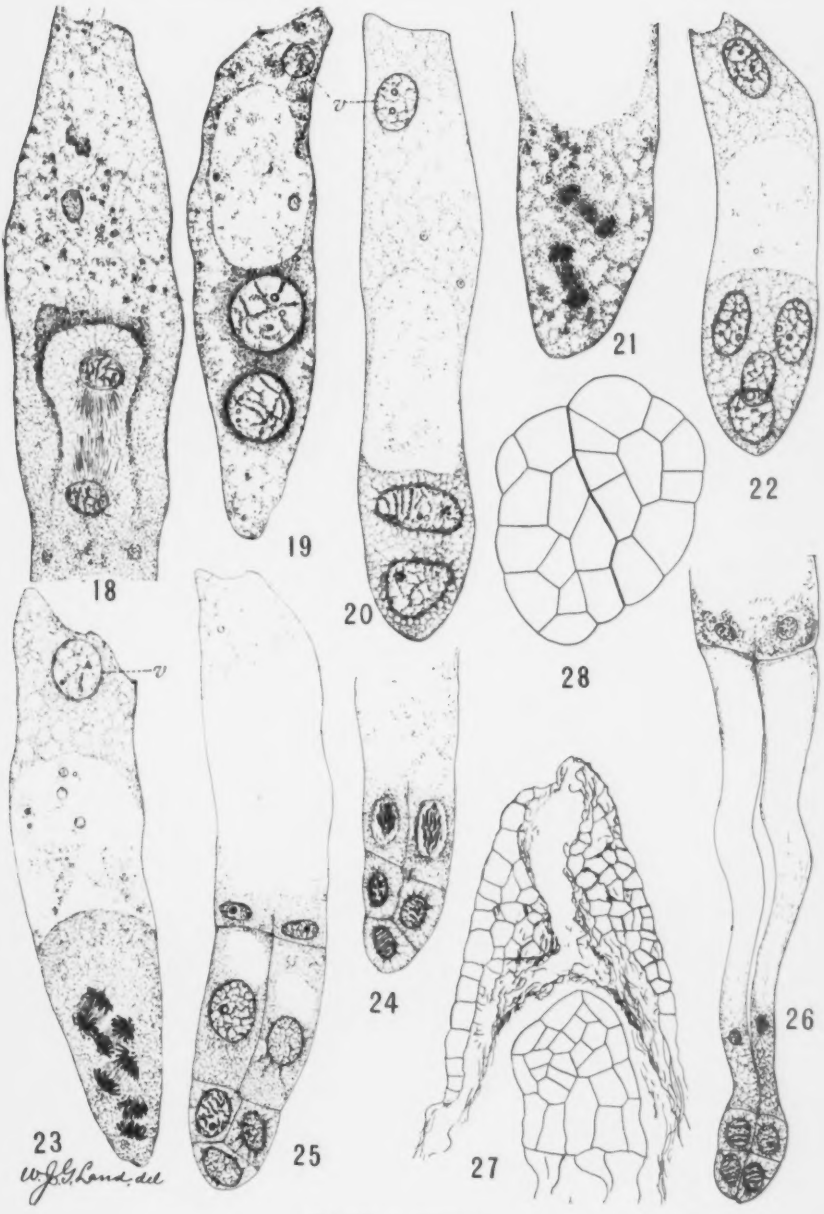

LAND on THUJA

FIG. 1. Pollen grain shortly after separation of tetrad.

FIG. 2. Pollen grain showing tube nucleus and generative cell.

FIG. 3. Pollen tube with tube and stalk nuclei in advance of the body cell.

FIG. 4. Pollen tube entering nucellus.

FIG. 5. Body cell preparing to divide.

FIG. 6. Tip of pollen tube with two male cells and tube and stalk nuclei.

FIG. 7. Male cells at the bottom of an archegonium which failed to function.

FIG. 8. Longitudinal section through upper end of prothallium, showing archegonium initials.

FIG. 9. Archegonium complex after neck cells have been cut off.

FIG. 10. Archegonium complex just before cutting off the ventral nucleus; jacket cells very active, neck cells disintegrating, and body cell preparing to divide.

FIG. 11. Transverse section through middle of an archegonium complex, showing the large vacuoles.

FIG. 12. Cutting off the ventral nucleus.

FIG. 13. Probable division of the ventral nucleus.

FIG. 14. Male cell entering the egg.

FIG. 15. Male nucleus after slipping out of its cytoplasmic sheath.

FIG. 16. Male and female nuclei in contact.

FIG. 17. Division of ventral nucleus in upper end of oospore; only three of the four nuclei shown; below is the proembryo, with the suspensors beginning to elongate

FIG. 18. Division of the fusion nucleus.

FIG. 19. The two nuclei resulting from the division of the fusion nucleus; the ventral nucleus is above.

FIG. 20. The two nuclei at the bottom of the egg.

FIG. 21. Second division of the proembryo.

FIG. 22. Four nuclei resulting from the second division; the ventral nucleus above.

FIG. 23. Third division of the proembryo; this figure shows the last simultaneous division of the nuclei.

FIG. 24. Upper tier of nuclei dividing to form suspensors.

FIG. 25. Second tier elongating into suspensors.

FIG. 26. Suspensors, with embryo.

FIG. 27. The most advanced one of a number of embryos growing upward through the nucellus; in the preparation from which the figure is drawn there are the usual number of embryos growing downward.

FIG. 28. Transverse section of an embryo, showing bipartite appearance.

THE RISE OF THE TRANSPIRATION STREAM: AN HISTORICAL AND CRITICAL DISCUSSION.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XXXVIII.

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[*Concluded from page 193.*]

VIII. The theories ascribing the rise of sap to the atmospheric pressure and to differences in the tension of gas within the wood are not fundamentally distinct. It is true that Böhm felt called upon to drop the former when he accepted the latter; and R. Hartig advocated the latter while altogether discrediting the other. But if the living cortex of the root be regarded as inactive, it is clear that an excess of pressure outside will force water into the root, just as surely as it will make it move in the wood toward the point where the pressure is least. This is realized in dead roots, which, as is well known (Saussure; Hansen; Janse; Böhm, 1889), can temporarily at least supply the demands of transpiration. In the living root the influence of the atmospheric pressure must be the same; it may be opposed by friction or aided by osmosis; but in itself, so long as there is water outside the root and the pressure within is less than an atmosphere, it will push the water inward. Pressing water into the root must directly or indirectly press other water up the stem. The cortex of the root is easily permeable to water; and water outside but in contact with it will be subject to and will transmit the full pressure of the atmosphere. There is, therefore, no foundation for the idea (Strasburger, 1893: 55; Goppelsroeder, 1901 : 211) that the atmospheric pressure cannot operate to raise the transpiration stream merely because the walls obstruct the passage of the air itself. When root pressure is not active the atmospheric pressure is probably the chief cause of the passage of water into the root; at least this conclusion is indicated by the excellent work of

Vesque (1884), who found the absorption by oleander roots to be proportional to the pressure, both below and above one atmosphere. Vicia was found less sensitive to slight differences in the pressure, whence it appears that osmosis plays a larger part in its absorption of water.

The atmospheric pressure theory says that the water-conducting structure of a tree is something like a large water barometer. When water is withdrawn from the top of it to be evaporated, the atmospheric pressure against the bottom forces water up to make good the loss. The water column, instead of being continuous, is broken by bubbles, each supposed to have a tension corresponding to its height in the column. The tension of these bubbles will cause a local movement, and their elasticity will make any adjustment of a disturbance gradual, so that the dependence on the atmospheric pressure is not immediate, but ultimate (and entire).

The evidence for this theory, aside from Vesque's work, which has never been adequately appreciated, is chiefly the presence of rarefied air in the tracheae. We have already dwelt sufficiently on the extent of this rarefaction. The theory demands that there be an uninterrupted decrease in the tension of the air from below upward; this must hold, however, only in each individual water-path, and need not be at all true of the tree as a whole. R. Hartig (Die Gasdrucktheorie) is quoted as reckoning the difference in tension sufficient to move water between adjacent tracheae at 0.00004 atmospheres, and as making elsewhere an even lower estimate. Manometric determinations of the tension are practically valueless unless it is certain that they are made in the same path. All that has ever been proven (R. Hartig, Bot. Zeit. 1883, among others) is that the tension is on the whole less near the top of the tree, near where the water evaporates, than it is lower down. There is no sound experimental evidence that in any single water-path of any tree there is a constant increase in pressure all the way down to the roots. But on the other hand, the fact (Strasburger, 1893: 61–63) that in the crown of the tree differences in tension depend upon the intensity of the transpira-

tion, but not on the height, is not an objection to the theory, because in the crown there must be a poor opportunity to test the tension in the same path twice; and the transverse equilibration of tensions is limited even in Tilia, where it is easiest.

The time and place of the occurrence of low tensions in trees permit no doubt as to their being the result of transpiration. They occur in the youngest wood, whence the water is drawn to the leaves; and they are greatest in the summer season of most active transpiration, in spite of (and also as a cause of) the fact that absorption by the roots is most active then. The usual daily variation is very conspicuous. In mosses with specialized conducting strands energetic transpiration results in the same way in the appearance of greatly rarefied gas (Haberlandt: 1883, and 1886: 416). Not only is it a general rule that the tension is lower during the day, but in many cases the tension exceeds an atmosphere by night, giving way to a relative suction when transpiration becomes active, as was mentioned in discussing root pressure. In our climate this occurs in summer only in herbs, but Molisch (Ann. Jard. Bot. Buit. 1898) reports it in lofty Javanese woody plants.

That the lower tension following transpiration will have as its result a forcing up of water from below until the tension is at least in part eliminated is almost self-evident. I do not recall seeing this questioned, except in one or two passages by Strasburger. After finding that branches of Taxus and Tsuga can absorb water under almost no outside pressure, he denies (1891: 796) that the tension of bubbles in the wood has any importance. And in speaking of the possibility of low tension in the upper part of a tree (1893: 60), where he says "So müsste für diese Erscheinung eine andere Ursache als die der Wasserhebung gesucht werden," I am uncertain what "Ursache" may mean. But in many places Strasburger takes the other view. For instance (1891: 871), "Die auf tracheler Saugung beruhende Wasseraufnahme aus dem Boden kann dann (after transpiration ceases to be active) fortdauern, bis dass die Bahn mit Wasser gesättigt ist," and (1893: 81) "Vor allem muss aber die negative

Gasspannung, die in solchen (zeitweise entleerten) Bahnen herrscht, zu deren Wiederfüllung beitragen. Ihr Einfluss dürfte stets dominirend sein."

That transpiration and absorption are not parallel has always been inexplicable except on the basis of a storing up of the "suction" (rather, reduced tension) by the rarefied gas in the tracheae. And this involves the assumption that the differences in tension suffice, in practice if not in theory, to lift the water.

The one great objection to this theory is that the pressure of one atmosphere at sea level is equal to that of a column of water only 10^m high, which is no considerable part of the height of large trees. The bare dogma "it cannot be" is not instructive nor stimulating, but has been much too effective in discrediting this theory. The atmospheric pressure certainly cannot cause an upward flow of a continuous column of water more than 10^m high; but except when root pressure is active and can act with the atmospheric pressure, it may well be doubted if such a column of water ever occurs in trees. The atmospheric pressure would be ineffective against it solely because its downward pressure would be greater. But it is well known that pressures in excess of an atmosphere never are found in actively transpiring trees.[1] At whatever height the pressure in the tree may be tested, it is always found such that the local application of a counter pressure of an atmosphere would move the water present upward. The problem is to explain how a pressure of one atmosphere decreases so gradually that it does not become zero in several times 10^m height of water, air, and wood. Denying the possibility has distracted attention from the real question. The conclusion of this paper will be occupied with this problem.

IX. The belief that the forces operating below — atmospheric and root pressure — and the tension of whatever kind arising from evaporation by the leaves were altogether inade-

[1] For the explanation of Figdor's (1898) apparent discovery that high pressures are the rule in the tropics, see Molisch (1902: 53–55; also Gregor Kraus, 1895: 216). A. N. Prentiss is referred to by Clark (1874: 190) as telling of trees in Brazil which, if cut during the dry season, suck in air "so forcibly as to cause a sound, amounting almost to a groan."

quate to explain the ascent of sap left the one obvious alternative of some motive agent distributed along the stem. The only modern theories along this line making any pretence at completeness have sought this intermediate force in the activity of living cells. There are two distinct theories of this kind, proposed respectively by Westermeier and Godlewski. According to Westermeier's theory, the living cells constitute the chief path of the transpiration stream, and their osmotic activity furnishes the motive power. The vessels, and even some intercellular spaces (1884:1106–10), serve as reservoirs or landings for the water, its running down in them being prevented by capillarity. The limit on the height to which the water can well be carried at a stretch in the parenchyma alone is placed by Westermeier at 3^{cm}. It is not shown in detail that the structure of any tree is such as this theory demands; still, the association of tracheae and parenchyma is a striking phenomena, from which, in fact, Westermeier got his idea. Such rapid movement by osmosis in living cells as this theory provides for is known nowhere else.

Godlewski's theory is in better accord with the generally accepted fact that the tracheae are the chief path of the transpiration stream; he holding that the water passes through living cells, the medullary rays, only at occasional intervals, receiving each time an impulse like that of root pressure, which carries it some distance up in the tracheae. Godlewski's idea was that the water moved upward instead of falling in the tracheae, when forced into them by living cells, because of differences in the tension above and below; which would make this theory subject to the same limitations as if the living cell feature were omitted (Zimmermann, 1885). Janse (1887:34–48) sought to obviate this difficulty by ascribing the water's failure to sink to friction. There is no escaping the fact that water will sink in wood (unless hindered by too much air) by its own weight. For this explanation to hold it would be necessary then for the living cells to raise the water faster than it could run back, which is not to be expected of osmosis, and would be very wasteful at best.

Janse suggests that the medullary rays will always pass water in the same direction, being able to distinguish the upper end by virtue of the stem's "polarity." But the weight of evidence ever since Hales has been that the water moves with equal readiness in either direction (Hoffmann, 1850: 842; Hartig, 1861: 22; Unger, 1868: 397; MacNab, 1874: 363; and Böhm, Ber. Deut. Bot. Gesell. 1890. On the other side Rauwenhoff, Reinhold, and Meyer, 1897, the latter only *contra* Böhm's work). In view of the fact that the transpiration stream does not become more concentrated as it rises, the mechanism of its propulsion must be different from that we have found most likely in root pressure. Godlewski, therefore, embraces Pfeffer's suggestion that a stream may be driven through a cell if a difference in internal concentration be constantly maintained; and he seeks the energy to keep up this unequal distribution of solutes within the cell sap in respiration. The expensiveness to the plant of this operation is evident.

Aside from the isolated instance reported by Janse (1887: 30–32), in which the path of eosin carried by the transpiration stream seemed to traverse the medullary rays, the positive experimental evidence used to prove the activity of living stem cells is that "root" pressure is greater farther up than at the base of a stem, and that rootless parts of plants bleed. Baranetzky (Abh. Naturf. Gesell. Halle 1873: 51–53) is authority for the greater pressure higher up, but he experimented with only four individual Helianthus and Ricinus plants, too few to guarantee the results; and Detmer (1877. cf. Wieler, 1893) reached the opposite conclusion. I have found the pressure of Helianthus higher on the whole when the seedlings are cut near the ground, but have tested only a dozen plants.

Baranetzky (*l. c.* 53) also cut a piece fifteen feet long out of a maple stem, closed both ends, cut a series of wounds in it, and peeled the lower end and set it in water. After eight days the wounds, especially the lower ones, began to bleed daily, from 11 A. M. to 1:30 P. M. It was exposed to the sun from 10:30 until evening, and in spite of the fact that the temperature in the

shade rose until 3 P. M., it is possible enough that its bleeding was coincident with its hours of becoming warmer. That the sap became bitter and astringent shows that its extrusion was not due to any normal activity of living cells; but the true explanation is probably the same as that of Pitra's experiments. Pitra made numerous experiments differing from Baranetzky's in that the piece of a stem was submerged except the upper end, which was provided with a manometer. Bleeding was likely to begin after eight or more days. Pitra had here substantially the same physical apparatus as an osmometer. The sap in the wood is slightly more concentrated than the water outside; between them the cambium or youngest immature wood would be a very imperfect semipermeable membrane, and the callus or healing tissue formed in and over the exposed surface within a few days (cf. Molisch, 1902; Wieler, 1893: 150) would make a much better one. A continuous layer of uninjured cells between the sap and the water would insure success; accordingly when the leafy branch was immersed and the cut end, with the manometer attached, was above the water, a pressure was more certain to be developed. This experiment shows also that in such experiments the water moves toward the base of the stem just as well as toward the leaves. Wieler (1893: 30–33) has repeated these experiments, likewise making an osmometer each time, so that his results are most naturally construed as having no bearing on the normal movement of the transpiration stream. C. Kraus has published an enormous number of instances of so-called bleeding from various isolated parts of plants In at least a part of these the conditions were such that by the formation of a wound tissue an osmometer was formed. I have not had access to all of C. Kraus' work, but what I have seen makes me quite ready to accept the opinion of Molisch that the extrusion of water was always a direct or indirect effect of wounding, and without any relation to the rise of sap in healthy plants. Molisch's own work (1899) on the voluminous bleeding of sugar producing palms was more of a puzzle in the absence of information on the histogenetic results of the wounds inflicted, until his paper of

1902 classing this with the work of Pitra, Böhm (1892), and C. Kraus. Looked at in this way, we have here a complete layer of live cells formed across the water conducting tissues, making still another osmometer[2] — an enormous nectary. The water being drawn into this nectary from the conducting elements by osmosis, it is exactly the same, so far as concerns the problem of the ascent of the water, as though it were drawn by the same force into the transpiring cells of the leaf.

Strasburger, who can speak with most authority, says the structure of many trees, notably Dracaena (1893:17), is much less favorable to the action of living cells than is that of gymnosperms, which were Godlewski's chief subject of discussion.

The most conclusive argument against the activity of living cells in the ascent of sap is its moving freely upward in stems where the cells have been killed by poisons or by boiling. More or less injurious stains have always been used to detect the path of the transpiration stream. Of more violent poisons, $K_3Fe\,CN_6$ was carried up in experiments for the same purpose by Rominger, Hoffmann (1848; 1850: 796,842), Von Mohl (1851: 231), and Van Tieghem (118 *seq.*) Boucherie (1840), in experiments in which the poisons must have risen more than 10^m, had various ones absorbed, especially iron pyrolignite. This was also carried up more than forty feet in an experiment already described by T. Hartig (1853: 313), and was afterward carried downward in a reversed transpiration current in an experiment by the same author (1861: 23). Saussure (1804) let $CuSO_4$ be absorbed, which killed the plants after a few days. Dutrochet (1837: 214) found that H_2SO_4 strong enough to discolor them would rise in stems; from which he did not fail to conclude that living cells were unnecessary to its movement. Strasburger's work on the conduction of poisons culminated with an experiment (1893: 10–17; other work, 1891: 607–625) in which picric acid rose 21.9^m in an oak.

Experiments in which boiled parts of plants conducted water

[2] Osmometers, so-called, are not commonly used as real "measures" of osmosis; osmoscope would be a much better word.

have been made by Hansen, Weber, Janse (1887 : 21), Böhm (Bot. Centralb. 1890; 1892 II; 1893), Vesque (1891 : 583), and Strasburger (1891 : 645 *seq.*). Strasburger boiled the lower 12^m of a 15^m high Wistaria, after which water rose at least 10.8^m from the base. When part of a stem has been boiled, the living part above it usually wilts after a few days. Weber found — and Janse confirmed it — that the living part above, or both above and below, the boiled part had become impervious by the growth of tyloses, or other healing devices, such as would be used to cut off an injury arising in any other way. It is, then, the activity of the live part, and not any inactivity of the killed part which is the immediate cause of the stoppage of the transpiration stream. There is no direct evidence that any activity of living cells is necessary, even to keep the dead conducting elements in lasting proper condition.

It was never more difficult than it is now to say safely that any performance is not possible by living cells. But it has been most thoroughly proven that their assistance is in no way necessary in the ascent of sap; it is therefore exceedingly improbable. More than this, it is evident that if water be withdrawn from any vessel by living cells and returned to the same vessel higher up, or to any other vessel in easy communication with it, the water will run down again unless it be prevented by friction or by some force outside the living cells. Friction is not available, since water will sink in wood by its own weight; and without friction, a force which can hold it from running down can also draw it up, without any help from the living cells. The work of living cells in lifting water can be effective only when these cells form a closed layer without a leak. Root pressure is made possible by the presence of such a layer of cells. But an unbroken layer of living cells across the entire path of the transpiration stream, or even across so much of it as supplies water to a single leaf, is unheard of in the stem of any plant. It is the tracheae which are uninterrupted. It is precluded by its structure, then, that the stem of any plant should serve in the elevation of sap as the root does in setting up root pressure.

When Pfeffer (1892:258–267) attacked the problem of the rise of sap, by the method of eliminating impossibilities, Strasburger had cut out the assistance of living cells as this last resort; though Pfeffer was so reluctant to be left without any that he questioned the sufficiency of Strasburger's proof. As far as Pfeffer reached any conclusion, it is this (260): "Ohne irgend eine bestimmte Voraussetzung über die Mechanik der Wasserbewegung in den Leitbahnen, kommen wir also zu dem, übrigens auch schon aus anderen Argumentationen gezogenen Schlusse, dass das Wasser anderweitig, d. h. durch in den Leitbahnen entwickelte Kräfte, in die Höhe geschafft und somit das in solcher (! !) Weise auf höheres Niveau gehobene Wasser den aus den Gefässbündeln schöpfenden Zellen geboten wird." "Wie aber im Näheren der Betrieb zu Stande kommt, ist gänzlich unaufgeklärt."

X. Of the various theories on the ascent of the sap we have found no other to have so much in its favor, logically and empirically, as that which says the ultimate cause of the upward movement of water in the wood to replace the loss by transpiration is the pressure of the atmosphere against the water absorbed by the roots. To the sufficiency of this theory it is objected that at most the atmospheric pressure can push water up only 10^m, and this objection is not refuted, but rather better applied, when it is pointed out that the downward pressure of water actually occurring in transpiring trees of whatever height is never such that one atmosphere cannot overcome it. The kernel of the whole problem is, why is this atmospheric pressure exhausted so slowly with the ascent of the tree that, whatever height is reached, and however rapidly and forcibly water may be drawn from the wood, some pressure always remains?

Vesque (1884:195) proposes that in measuring the 10^m which the atmosphere can push up only the indices of water between the bubbles should be counted, for the bubbles have no effective weight. The suggestion is good as to water at rest; and would be valid and final as to the rising stream if the bubbles moved with the water; then our problem would have been

solved by Malpighi. But the bubbles do not move. As Vesque himself was first to show, the water moves past the bubbles, without as a rule disturbing their position. In the present state of our knowledge, this seems to require that liquid water be always continuous from one index of it to the next along the wall. If the pull from the leaves is operative around the bubbles, there is no known reason why that of gravity should not be. But if it were, the total pull of the water in the stem would seem to have to be equal to that of an unbroken column of water of the same height. And no such pull can be detected.

Every feature, active or structural, of the environment of the water in the wood is a part of the complex whose composite result is the rise of the water. Modifying any of these features must influence the movement of the water. Of two physiological factors — removal of the water by transpiration, and the pressure of the atmosphere — we know that in the entire absence of either the water does not rise. Any theory which leaves out of consideration any part of the environment of the water might reduce the rise of it to an equation, but would not prove its right to acceptance. The atmospheric pressure theory, taken alone, is in this negligent position. To be complete, it must reckon with the tensions, surface or other, and with the friction, external and internal, of water moving in the lumen, against the walls, and at times in the walls of the wood. Absolute completeness, such as would explain the rise of water in beech but not in oak wood, is not at present a goal; but any theory ought certainly to include every phenomenon of the rise of water in many or all trees, or show that those omitted are irrelevant.

Nothing about the rise of water strikes one who has seen it as more characteristic than its movement between the bubbles and the wall. When transpiration is at all active, the water must travel more than half of its course in this way. It must move very much more rapidly here than in places where it fills the entire lumen. Surely no theory can be complete which does not include a mechanical explanation of this passage of the bubbles.

Science has become so broad that no man can be proficient

in many of its branches, and as the field of labor is divided, we turn to the physicist for skill in the solution of such purely mechanical questions as this must be. But while as keen a worker as Schwendener can find no physical ground for even the existence of a flow past bubbles, we have only ourselves to rely on for an explanation. The soundness and thoroughness of physiology is usually measured by its nearness to physics and chemistry; but in the present state of physical knowledge on this point no theory can rest on it and be acceptable. The problem is distinctly outside of my province, and the experiments I have made on it were for the personal satisfaction of feeling a new field, without any thought of clearing it. I will speak of only two or three of them.

As stated before, Vesque's experiments in glass tubes are easy to repeat. If a coiled hair is pushed into a wet tube it straightens in part, but will hold up an obstruction such as a bit of copper slid down from above; and this will afford considerable opposition to the rise of a bubble let in from below; while the hair runs down the side of a tube from the water above to that below the bubble. With care, bubbles can sometimes be held in place by the hair alone, but not as certainly. I have found it convenient to set the tube, so fitted up, in a vessel of water on the top of a microscope; the focusing adjustments of the microscope served to elevate or lower the vessel. Measurements were with a cathetometer. The meniscus in the tube being well above the obstruction to the bubble, the vessel was slowly raised; the bubble was stationary, while the meniscus higher up slowly rose. Nothing else was to be expected; this need show only that the surface tension in the angles formed by the hair and the wall is sufficient to hold in the angle water which connects that above the bubble with that below it.

In a Jamin's chain, the bubbles moving with the water, and no water passing them, capillarity will hold the highest meniscus an indefinite height up in the tube. If Vesque's suggestion, that an atmosphere should lift in the wood a total of 10^m of water, exclusive of bubbles, is tenable, the height to which the highest

meniscus in a tube with a bubble past which water flows should be greater than in the same tube of unbroken water; but at first sight that looks unlikely. Some experiments seem, however, to indicate that it occurs. Thus, in a tube 1.3 mm in diameter (as nearly as I could measure), the height from the water outside to the meniscus within was 23 mm; with two bubbles in the tube the height was 23.9 mm; after they were removed it was 23.1 mm. But in most instances I found the added height, after introducing a bubble or two, to be about 0.1 mm, which is too little to rely on as anything. Working with a tube obstructed by a hair alone, I have seen a bubble without any other provocation than an accidental jar, slide above the hair and make a Jamin's chain, and carry about 3 mm of water with it, so that the total water held up was 27.2 mm, instead of 24.2 mm. The energy to do this must have been furnished by the change in shape of the bubble. One more of these experiments will suffice. A piece of glass tubing was blown in the shape illustrated, and a bubble put in whose outline is shown by the curved lines at the two extremities of the figure; a hair passing around the bubble. Keeping the tube upright, it was subjected to an added pressure of 70 cm Hg. Within ten minutes the bubble was reduced one-half, as represented by the inner bounding lines; the immediate effect of compressing the bubble was to make the meniscuses at its two ends of different shape, and this difference caused water to flow up around the bubble.

While these experiments and others show the facility with which water can pass bubbles in vessels of uneven contour, they throw no light on the force which carries it around the bubbles in the tracheae; which is the question that needs answering. The ease of the movement, and its rapidity, and above all the pressure relations involved in the tracheae, are still quite in the dark. Since the water moves farthest and fastest here, it is greatly to be hoped that physicists will soon take a position with which we can get in touch.

Another problem hardly less in the dark than the physics of

the films of water around the bubbles is the resistance to be overcome by the movement of the transpiration stream. These two problems have much in common, but this one admits of a more conclusive experimental answer. According to most of the evidence we have, more energy is required to overcome this friction than in the actual lifting of the water. But this evidence is most noticeable for the discrepancies in it — cf., *e. g.* Janse with Strasburger or Sachs. In the most recent work on this subject, Curtiss (1901) concludes that the resistance offered by a stem to the flow of water at a fixed rate is not proportional to the length of stem. He also finds that the same force is required to overcome this resistance, whether it is applied as a pull or a push; which at most can be the case only within limits, because of the influence of the tension on the size of the bubbles. The rapidity of the movement of water can involve no inconvenient measure of friction, or the plant would provide for a slower current by allowing the conducting tissue a greater cross section. Instead of doing this the tree restricts its conducting area with tyloses, "gum," and changes in the wood itself, whose only known effect where they occur is to hinder the movement of water. In many trees, as in Robinia, the specialization is most decidedly toward the restriction of the transpiration stream to the youngest wood.

If it should be proven on the physical side that the water surface in contact with the bubble, in breaking half of the bonds that held it in the liquid state, had acquired some of the motility of a gas, the clearing up of the physics of the water surface would altogether alter our attitude in theory toward the friction problem. The idea that the surface of a liquid is more rigid than the interior, certainly arose from faulty experiments, but the truth of the matter is yet to be shown. If it should be found that the surface shared the properties of gases again in their relative indifferences to altitude, as Sachs suggests for the water of imbibition — and as is not at all impossible with a half-way vaporized surface — the calculation of the 10^m of water as the sum of the liquid indices alone will be justified at once. It is conceivable even that the elevation of water by surface tension

in the stem be active, the source of energy being the cooling of the stem, which would remove the 10^m limitation altogether. Arendt's observations, apparently of ascending currents maintained by capillarity, have not to my knowledge been corrected or explained. It is safe to assume that the plant does not work on a dangerously narrow margin, and 10^m of water in a tree 100^m high would leave a proportion of air for which we know no parallel. But it is idle to take advantage of what we do not know to spin out speculations.

This is not a satisfactory state in which to leave a subject. But it may still be regarded as something in "this most nebulous of subjects," as Darwin calls it, to have pointed out where our theories fail, and where our densest ignorance lies. The rise of water to make good the loss by transpiration is due to the pressure of the atmosphere, or to this and other forces cooperating with it and regulated by it. Much farther than this we cannot go until there is a physical explanation of the repeated botanical observation of the passage of water between bubble and wall.

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The absence of anything like a complete and easily accessible bibliography has been a difficulty in the preparation of this paper, which I have tried to spare for future work. Not only has there been a dearth of reference and credit to earlier work, and consequently a great deal of republication, but a surprising number of inaccurate references add to the difficulty. From this list of titles I have therefore omitted all those of works which I have been unable to consult and verify in person, excepting a few which it has seemed best to refer to on hearsay; these appear in brackets. In spite of this limitation, the bibliography will hardly be found glaringly incomplete. The few general texts listed contain matter on this subject which might appropriately have been published separately. The few purely physical works included here are to complete references in the body of this paper.

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SOME NOTES ON THE ECOLOGY OF THE DELAWARE COAST.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XL.

LAETITIA M. SNOW.

(WITH MAP AND TEN FIGURES)

IN July and August of 1901 the observations here recorded were made at Rehoboth Beach, Delaware, as a small addition to the increasing collection of data from the Atlantic seacoast. In sequence and nomenclature an attempt is made to harmonize these results with those obtained by Mr. Kearney[1] and Dr. Harshberger[2], on Ocracoke island and the New Jersey coast, respectively. The Britton and Brown nomenclature is used throughout, with the synonyms from Gray's *Manual*, where such occur, in parentheses. The list of plants does not claim to be complete, as the work was done during the summer months, and therefore the flowers of many species had disappeared, while other forms had not yet flowered, making identification difficult and at times impossible. Many forms were doubtless overlooked in the one or two visits which limited the opportunities for study in some parts of the field. The algae and fungi were not studied, while the lichens and mosses received the most superficial attention.

I. GEOGRAPHY.

The region studied extends from Cape Henlopen to a little over a mile south of Rehoboth, including a tract of land about six and a half miles long, by one-half to one mile in width, lying on the mainland, instead of on a fringing chain of islands, which is the usual condition along the Atlantic coast. The trend of the

[1] KEARNEY, T. H., The plant covering of Ocracoke island. Contrib. U. S. Nat. Herb. 5: 261–319. *figs. 18.* 1900.

[2] HARSHBERGER, J. W., An ecological study of the New Jersey strand flora. Proc. Acad. Philad. Oct. 1900.

coast line is almost due north and south, and the ocean currents come predominantly from the southeast.

II. PHYSIOGRAPHY.

A. Topography.—From the northeast end of Maine to the Florida peninsula the Atlantic coast is more or less fringed with islands, the shore lines of Delaware and Maryland being no

FIG. 1.—Shore south from Rehoboth, showing sandstone layer upon which is a dune; Douglas House at left, one mile to the south.

exception to the general rule. Here the bays and lagoons extend far into the mainland, usually surrounded by swampy tracts, broken up into sub-bays by low lying islands, and often connected by slowly flowing streams. In the course of time the lagoons and bays become filled up by sediment and plant remains. This process of filling up could be studied with great advantage in the Henlopen region, for all the stages from lakes through storm-flooded areas and swamps to the meadows are found, although the lagoon stage is past.

The sea beach is smooth and usually has a very gradual slope; the sand is fine and compact and is not easily drifted, therefore

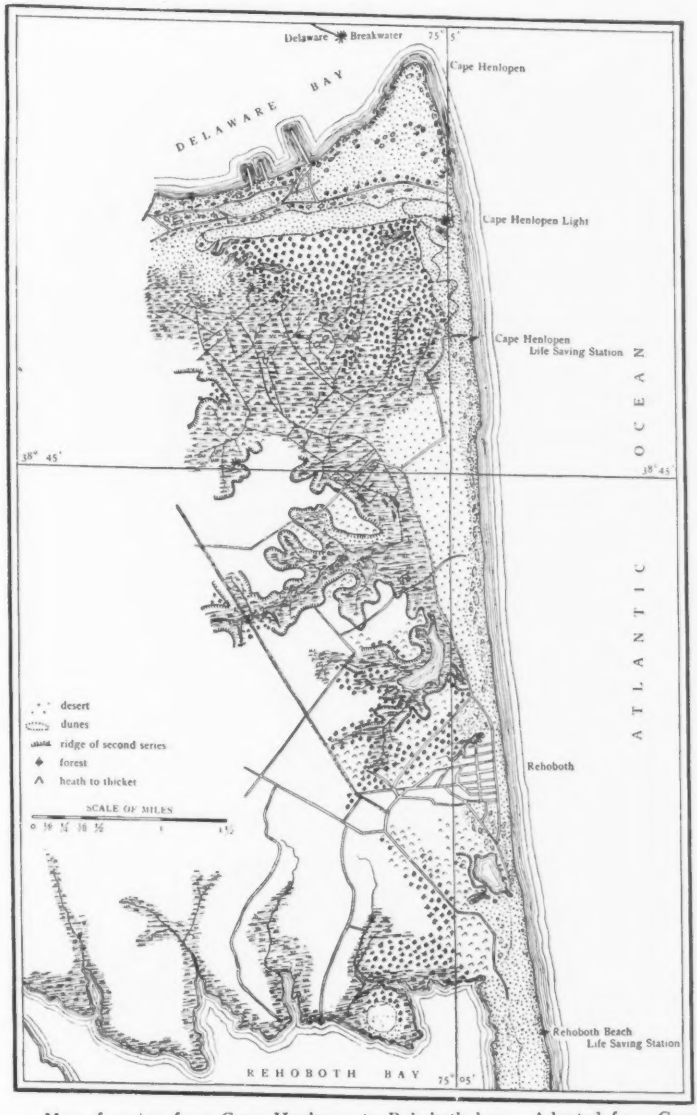
there is a tendency for low, more or less fixed dunes to form. Diagonally across the cape, however, is a large active dune, which by comparison with the 75-foot lighthouse seemed to be about 80–90 feet high. To the southwest of this are several smaller active dunes, becoming lower and more stable toward the south. A row of small dunes, somewhat fixed, edge the beach around the cape, enclosing a region of swamps, meadows, lakes, and low dunes. South along the beach extends a line of dunes, with a second series back from it, the distance between the two varying greatly at different places. Meadows, swamps, lakes, and small dunes occupy this space.

The second series extends in a very irregular line across the cape (see map), and since these dunes must have been blown in from the coast it is natural to suppose that the coast at one time was parallel to them (S.E.-N.W.), instead of projecting to the northeast as now. The supposition that Cape Henlopen has grown out from a S.E.-N.W. coast, and is still growing, is supported also by the formation of hooks on the western shore by the southeast ocean currents. Such cape and hook formation is described and figured by Gerhardt[3] from the coast of Europe.

Back of the second series of dunes a plain slopes to the thicket and forest, broken in places by meadows and small dunes, and interrupted by fields. This plain, for want of a better name, I have called a "heath;" physiographically it corresponds with that type, although it is not characterized by the typical plants.

B. Soil. — 1. CHARACTER. — The soil is predominantly sandy throughout, usually nearly to the surface, where a thin layer of humus appears in the moister regions. The beach is nearly pure sand, with a few patches of clay in hollows, where it is deposited by the wash of storms. From Rehoboth for about a mile south there crops out along the beach a deposit of sandstone. This being much more resistant than pure sand stands out in step-like structures, upon which dunes are usually superposed (*fig. 1*). In

[3] GERHARDT, PAUL, Handbuch d. Deustch. Dunenbaues. Berlin. 1900. pp. 43–46, 61–63.



Map of region from Cape Henlopen to Rehoboth bay. Adapted from Coast Chart no. 127, U. S. Coast and Geodetic survey.

several places, however, the dunes have either not formed there, or have passed back, leaving a golden brown slab of hard material. On the beach pieces of iron ore were found, washed from an undetermined source. Back in the dune region are tracts of land almost totally destitute of vegetation (*fig. 2*). These desert spaces are rain-washed in times of storm, and hold water for some little time, the water washing into the depression

FIG. 2.— Bare space between dune series; second series immediately beyond, on crest of which a thicket is forming; forest beyond.

from a higher region, and then evaporating, covering the ground with a deposit of sand and clay, which becomes baked in the hot sun. The ground is so unfavorable for the existence of plants, that very little vegetation is found here. In the swamps and meadows a layer of humus covers the sand to a greater or less depth, according to the character of the vegetation, the exposure, and the length of time of deposition.

2. SOIL WATER.— Water level is very near the surface, in most places only a slight depression being needed for the development of a swamp. The water furnished by pumps in the vil-

lage is strongly impregnated with iron, showing that a stratum of ferruginous material underlies at least part of the region.

III. CLIMATOLOGY.

A. Rainfall. — Besides lacking state geological and topographical surveys, Delaware has no Weather Bureau station, and therefore the statements concerning the climate must be very general. From the Rainfall Division of the U. S. Weather Bulletin, 1897, the following facts were obtained. The mean annual precipitation is 40–50 inches in the Middle Atlantic states. The distribution here is more uniform than in any other part of the country, 20–25 inches being the usual amount in the growing season (April–September), the least recorded for this period being 10–15 inches.

B. Heat and light. — During the two months spent at Rehoboth a very imperfect record of temperature and direction of the wind was kept, and in the absence of accurate reports the results will be used for comparison, The temperature figures for the New Jersey and North Carolina stations were kindly furnished by the U. S. Weather Bureau, the mean temperature for July and August, 1901, being as follows:

	July	August		July	August
Atlantic City, N. J. -	75	74	Cape May, N. J. -	75.6	73
Rehoboth, Del. -	77.7	78.4	Cape Hatteras, N. C.	78.9	79.5

Even on cloudy days the light on the coast is more intense than inland, on account of the reflection from the sand surface, while on bright days it is almost blinding. The amount of heat radiated by the sand is considerable, and taken in conection with the reflected light must necessarily have great influence upon the flora, only those plants appearing that are able to adapt themselves to these severe conditions.

C. Wind.—The direction of the wind, as well as its force, is very important with reference to the shape and size of the dunes. For the two months during which these observations were made the prevailing wind was southwest, alternating with northeast during July, and becoming more variable in August. No observations being made during the other months, no conclusions as to

the prevailing wind for the year can be drawn. The oaks and cedars bend away from the shore, as is usual, their outer branches suffering from the salt-laden wind, while the more protected limbs grow fairly well, thus producing a one-sided plant. The prevailing wind is not necessarily the dune-forming wind. For that other factors must be considered: the strength of the wind, the sweep over an expanse of surface, the absence of obstacles in the path, and lastly the angle at which it meets the shore. At Cape Henlopen the northeast wind is probably the strongest, having a sweep over the mouth of Delaware bay, and meeting the shore at a large angle; hence the dune is moving across country southwest. Farther down the coast the northeast wind meets the shore at a small angle, while the lighter east wind strikes perpendicularly. In this case the dune movement depends upon which factor is the stronger. The dunes here have become practically fixed, but what little movement there is appears to be directly west.

IV. PLANT FORMATIONS.

As a matter of convenience in harmonizing the two regions, the order used by Dr. Harshberger is adopted here so far as possible. Although adjacent situations, the conditions differ somewhat, because the region from Henlopen to Rehoboth bay is at a higher stage of physiographic development than the New Jersey beaches.

A. Treeless open.—1. BEACH FORMATION.—(*a*) *Lower beach.*—For reasons pointed out by Dr. Cowles[4] and Dr. Harshberger[5], the lower beach is incapable of supporting vegetation. We find it composed of bare sand, extending back, usually in a gentle slope, to the line of summer driftwood.

(*b*) *Middle beach.*—(i) Succulent zone.—At Rehoboth and northward the summer tides wash up to a ridge of driftwood and débris, where the loose sand first gathers, seeds rest and

[4] COWLES, H. C., The ecological relations of the vegetation on the sand dunes of Lake Michigan. BOT. GAZ. **27**: 114–185. 1899.

[5] *Loc. cit.* 639.

germinate, and such plants as *Cakile* sp., *Salsola Kali*, *Xanthium* sp., and *Atriplex arenaria* are found. Here also we find tufts of *Ammophila arenaria* (*A. arundinacea*), although it is not a character plant. This succulent zone is in some places confined to the ridge of débris around the bases of the low dunes, in others it extends much further back. It may reach many feet inland, to the foot of the higher dunes, or may even form channels by which the sea enters inland lakes in times of storm. The name of the zone indicates the structure of two of the characteristic species, Cakile and Salsola, and of the rarer Atriplex.

(ii) Low Ammophila dune zone.—From the line of summer driftwood to that of winter driftwood has been called by Dr. Cowles[6] "middle beach," while above the winter drift line the "upper beach" extends to the foot of the dunes. Here conditions are different. The winter drift line usually lies at the foot of the higher dunes, although logs are sometimes found on the low dunes. Hence there is no "upper beach" corresponding to that on the Lake Michigan strand, but what corresponds to the "middle beach" is more or less distinctly divided into two zones, which are designated here as "succulent zone" and "low Ammophila-dune zone." As the name indicates, the upper belt is characterized by low dunes held by *Ammophila arenaria*, in association with *Panicum amarum* and *Cenchrus tribuloides*, while scattered mats of *Euphorbia polygonifolia* and bunches of *Oenothera humifusa* occur. Xanthium comes up from the lower zone in places, and *Leptilon canadense* (*Erigeron canadensis*) wanders to some extent from the higher dunes. From the fact that the winter drift line lies back of these dunes, it seems probable that they are of annual formation. This question was not settled definitely, but in July they appeared to be rather large and firm for spring planting. North of Rehoboth the succulent zone is very narrow or entirely wanting. The beach is wide and bare and slopes to the first ridge of dunes, the low Ammophila-dune zone being omitted, or no distinction appearing between it and the next belt. At the Cape the same conditions obtain, the

[6] *Loc. cit.* 115.

lighthouse dune coming down, a bare, loose slope, to the beach. South of this is a hollow, formed by active dunes, and in which lies a swamp. Just in front of this swamp are the remains of the only low Ammophila dunes in this part of the region.

2. DUNES.—(*a*) *Outer series.*—South of Rehoboth this outer series is practically fixed. The sea face is exposed to storms from the sea, and is sharply eroded. North of Rehoboth this series is more active, being formed of loose sand partially held by Ammophila, the activity increasing until the lighthouse dune

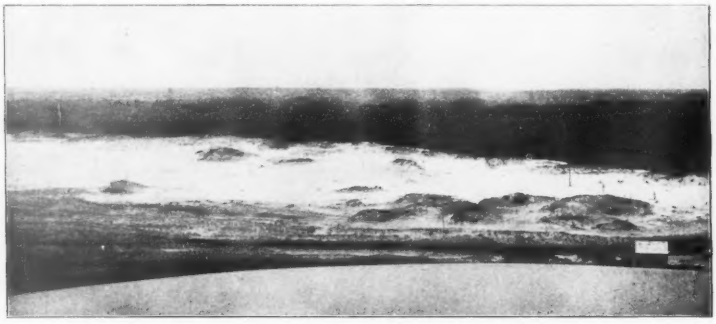


FIG. 3.—Southwest from lighthouse; lighthouse dune in foreground; swampy hollow at center; active dunes ("pine graveyards"), beyond which is a pine forest.

forms the climax. In this region they have a rounded form due to their activity. For most of the distance from Rehoboth to the Cape this series varies in height from 6–10 feet, getting higher to the north, where it culminates in the 80–90 feet lighthouse dune. In places it slopes from its crest into a heath, although it is usually followed by a dune complex or swampy meadow. Just south of the lighthouse dune lies the previously mentioned semicircle of active dunes enclosing a swamp. Other dunes stretch in a S.E.-N.W. direction, showing a northeast wind action. On the windward slopes of these dunes are several "pine graveyards"[7] (*fig. 3*), the remains of the forest over which the dunes are now passing. A little further south, at the

[7] COWLES, *loc. cit.* 298.

life-saving station (see map), the dunes have retreated quite a distance, and the place now occupied by active dunes was once a line of fixed pine dunes, for the active crest shows knobs still held by pines, and the dead trunks falling on the windward side. Coming from the beach over the waste of drifting sand, back of the life-saving station, and climbing to the crest of this active dune, one is startled by the contrast formed by the view towards the west with that on the windward side of the ridge. The dune is sweeping into a marshy meadow, apparently stretching for

FIG. 4.—Southwest from life-saving station dune; extreme right, rejuvenated face of old pine dune appearing again at center; active dunes to left; desert waste in middle distance showing a grass island.

miles to the southwest, and cut up towards the coast by ridges, upon which stand tall pines. One ridge is seen running nearly perpendicular to the active dune, and others at smaller angles. *Fig. 4* shows the rejuvenated face of one of these ridges. Between this rejuvenated dune and the shore just south of the life-saving station lies an active dune complex, containing meadows and swamps. Further to the south the complex spreads out and borders a broad level desert reach (seen in the distance in *fig. 4*, partially covered by water), the outer line of dunes following the shore, the inner ridge swinging off to the southwest. As the outer series north of Rehoboth is the frontal ridge, it has the sloping sea face sparsely covered with Ammophila, as is the case

with the low frontal dunes south of the village. South, however, the face of the first series of higher dunes is eroded, more probably on account of the fixed condition of the dunes than from any protection which the frontal line offers. This eroded surface has very little vegetation, some few plants from the top having fallen and taken root. In places where the erosion is not so great, this slope is characterized by Ammophila, *Euphorbia polygonifolia*, and *Leptilon canadense*. Over the edge, on the more protected slope also appear *Cassia nictitans*, *Oenothera humifusa*, *Strophostyles helvola* (*S. angulosa*), *Panicum amarum*, *Ionactis linariifolius* (*Aster linariifolius*), *Rumex* sp., etc., grading into heath forms, as *Lechea minor* (*L. thymifolia*), *Baptisia tinctoria*, *Myrica cerifera*, *Baccharis halmifolia*, *Rhus copallina*, *Diospyros virginiana*, followed by clumps of *Pinus rigida*, *Juniperus virginiana*, and *Quercus digitata* (*Q. falcata*). This first series borders the cape in a practically complete line, openings allowing the sea in times of storm to wash into the depressed area within. This region is covered mostly by swampy meadows (the dominant form being apparently *Spartina patens*) with open water in places. In this extended swampy area rise small rounded or elongated dunes, the higher ones topped by pines (*Pinus rigida*). In one clump of pines, occupying a depression surrounded by dunes, an undergrowth of *Myrica cerifera* and cranberry indicated a pine swamp flora. Such swamps doubtless occupy similar situations in the depressed area.

(*b*) *Hudsonia complex.*— Back of the protecting ridge of the first series lies a region of general depression in which at certain places low dunes extend in all directions, forming a complex, and held mainly by *Hudsonia tomentosa*. In places the formation is almost pure, in others various forms appear. These dunes are rounded in form, and about a foot or two in height, corresponding to the habit of the plant holding them. Swamps and meadows extend among these dunes, produced in most cases by the flooding in of the sea during winter storms, the ground remaining wet for most of the year. This complex is best seen south of Rehoboth, between the sea and Silver lake.

(*c*) *Swamps and meadows.*— The swamps found between the two series of dunes are undrained for at least part of the year, the history of Silver lake being a good example of what probably takes place in the majority of lakes and swamps of this region. During winter storms the sea comes in through openings in the outer ridge and floods the lake until its boundaries extend around the low dunes in its vicinity. During the summer months the lake margin retreats, leaving wet soil, and sometimes water standing in the depressions. This drying process nearly converts Silver lake itself into a swamp, very little open water being visible, an increase only occurring at times of unusually high storm tides and during showers. The first event occurs but rarely, and the amount contributed by the second method is not sufficient to supply the loss occasioned by evaporation during the hot dry days.

Around the edge of Silver lake grows *Scirpus americanus* (*S. pungens*), the growth being much more luxuriant at the north end, where the water is fresh. In places also occur *Cyperus ferox*, *C. diandrus elongatus*, and *C. Nuttallii*. At the south end of the lake, where the main entrance from the sea lies, were found such strand forms as *Polygonum maritimum*, *Dondia americana* (*Suaeda linearis*), and *Atriplex hastata* (*A. patulum hastatum*); while at the northern end the formations show a tendency toward fresh-water forms, passing from a swamp to a wet meadow and thence to drier conditions. Here we find such forms as *Scirpus americanus*, *Hydrocotyle umbellata*, *Hypericum canadense*, *Cassia nictitans*, *Pluchea camphorata*, *Linum virginianum*, *Linaria canadensis*, *Fuirena squarrosa*, *Xyris flexuosa*, becoming gradually replaced by *Spartina patens* (*S. juncea*), *Ambrosia artemisiaefolia*, *Solidago sempervirens*, *Erechtites hieracifolia*, *Gnaphalium purpureum*, *Erigeron ramosus* (*E. strigosus*), *Carex silicea* (*C. straminea moniliformis*), *Juncus tenuis*, *Fimbristylis castanea*, and *Scirpus subterminalis terrestris*. *Xanthium* sp., *Mollugo verticillata*, and other more xerophytic forms appear on low elevations and toward the dunes.

West of the lake lies a small meadow worthy of mention because it holds a plant assemblage not seen elsewhere, although

some forms present are the usual meadow species. Following the belt of *Scirpus americanus* and *Spartina patens* which borders the water of a small lily pond west of Silver lake is an association of *Strophostyles umbellata* (*S. peduncularis*), *Diodia virginiana*, and *Cyperus cylindricus*. Higher up appear *Hieracium Gronovii*, *Asclepias incarnata*, *Galium pilosum*, *Gnaphalium purpureum*, *Solidago sempervirens*, *Festuca rubra*, *Panicum amarum*, *P. sphaerocarpon*, and *Sieglingia seslerioides* (*Triodia cuprea*), out of which assemblage rise the stalks of *Kosteletzkya virginica*. One place a little more depressed supports *Iris* sp., *Achillea Millefolium*, *Daucus Carota*, *Rhexia Mariana*, *Lactuca canadensis*, *Prunella vulgaris* (*Brunella vulgaris*), *Salvia urticifolia*, and *Viola sagittata*. *Eupatorium hyssopifolium* and *Solidago canadensis* occur also, showing a tendency toward drier conditions.

That Silver lake extended in former years much beyond its present boundaries may be supposed from at least three things. First, by comparison with the chart of the Coast Survey no. 127, from which the map given has been copied, with what corrections appeared to be needed; second, from the presence around it of meadows, whose hydrophytic forms are being replaced by mesophytic species; and third, the presence of a clump of Iris on the east shore of the lake, but no longer in swamp conditions, being now on top of a flat dune.

The Hudsonia complex, back of the first line of dunes, and protected from the ocean winds, is subjected on its western edge to winds sweeping over the lake and the plain beyond. The dunes here show a windward slope covered with roots and débris of dead plants, uprooted and destroyed by the wind action (*fig. 5*). Toward the south end of the lake these dunes become low and are occupied chiefly by *Spartina patens*.

Across the lake, on its western border, rises the second series of dunes, bending round the meadow described above, and including in the bend a thicket of sumac (*Rhus copallina*), wax berry (*Myrica cerifera*), pines, cedars, oaks, and *Baccharis halmifolia*. Northward the depression between the two series is broad, and we find many mesophytic areas, probably the remains

of former swamps. Southward the depression narrows and for some distance is occupied by a road. Farther south it broadens out into a bare rain-washed area of hard baked soil with few plants, such as *Panicum sphaerocarpon*, *Antennaria plantaginifolia*, *Ionactis linariifolius*, *Diodia teres*, *Plantago aristata*, etc. This bare space passes seaward into a wet meadow which in turn slopes toward the dunes, *Spartina patens* replacing the meadow

FIG. 5.— East shore of Silver lake, showing at extreme right windward faces of dunes moving eastward; the swampy character of shore of the meadow extending northward.

forms, among which may be mentioned *Senecio tomentosus*, *Hieracium Gronovii*, *Gnaphalium purpureum*, *Viola sagittata*, and giving place to Ammophila toward the crest of the dunes, which here slope directly to the beach, no low dunes being present.

North of Rehoboth the two series open out in a V, near the apex of which lie Hudsonia dunes and swamps, one of which is a pine swamp. In this was found the typical pine swamp flora, *Osmunda regalis*, *Dryopteris Thelypteris* (*Aspidium Thelypteris*), *Oxycoccus macrocarpus* (*Vaccinium macrocarpon*), with *Xyris flexu-*

osa, *Rhexia virginica*, *Myrica cerifera*, *Rhus copallina*, and *Smilax rotundifolia*. No Sphagnum was found, however, during the one visit paid to this swamp. In another swamp in this region appeared an association of *Polytrichum* sp. and *Lycopodium inundatum;* while in still another *Iris* sp., *Hibiscus Moscheutos*, *Senecio tomentosus*, and *Viola sagittata* were grouped together.

On the Hudsonia dunes between the two series we find,

FIG. 6.—Hudsonia complex south of Rehoboth, a nearly pure formation; heath character is not developed; Hudsonia dune in left foreground.

besides *Hudsonia tomentosa*, *Lespedeza frutescens* (*L. reticulata*), *L. capitata*, *Meibomia obtusa* (*Desmodium ciliare*), *Cassia chamaecrista*, *Crotalaria sagittalis*, *Strophostyles helvola*, *Solidago canadensis*, *Euthamia caroliniana* (*Solidago tenuifolia*), *Myrica cerifera*, *Pinus rigida*, *P. virginiana* (*P. inops*), and *Juniperus virginiana*, which, with some bushes of *Gaylussacia resinosa*, *Vaccinium corymbosum*, *V. atrococcum* (*V. corymbosum atrococcum*), and *Oxycoccus erythrocarpus* (*V. erythrocarpon*) give the region a heath-like appearance (*figs. 6, 7*).

Farther north extends a low, flat meadow, swampy in places,

and containing lily ponds (*fig. 8*). Here were found such character plants as *Spartina patens*, *Hibiscus Moscheutos*, *Solidago sempervirens*, *Juncus scirpoides*, *J. tenuis*, *Sabbatia stellaris*, *Polygonum hydropiperoides*, *Xyris flexuosa*, etc., *Andropogon virginicus* and *Carex silicea* occupying a little higher ground. Some portions of this swampy meadow are undoubtedly under water during the winter

FIG. 7.—Hudsonia complex north of Rehoboth, with heath-like character somewhat developed; looking toward Henlopen light to northeast from the board walk; coast with first series of dunes shows in right background; clumps of Myrica, oaks, pines, with Hudsonia dunes in center background.

storms, the sea coming in through openings in the dunes of the first series.

This meadow area stops rather abruptly on its northern edge, at the desert-like expanse referred to above, which extends nearly two and a half miles north and south, by five-eighths of a mile at its widest point. Several inlets give an opportunity for the sea to flood this region during storms; in fact, the whole sandy area is reported to be covered with water "three foot deep" in winter,

but during the summer a part of it at least was dry. The process of filling up and reclamation seems to be progressing from the meadow, where adventurous plants are creeping out over the waste. This end must be higher than the northern end, for during a part of the summer the water remained in the latter. Several low dunes lie scattered like islands on this desert, their

FIG. 8.—North from board walk on second series, a continuation to left of *fig. 7*; meadow showing in right background with a lake at left; the continuation of the second series at left.

flora, consisting apparently of grasses and sedges, making a weak attempt to spread over the sand. Why has not this region a swamp flora? Swamps are frequent in the inlets, therefore lack of water is apparently not the cause. Only two trips were taken over this desert; they were excursions, therefore careful investigation was impossible. It gave promise, however, of yielding more interesting results.

(*d*) *Second series.*—This series has been mentioned so frequently in the discussion of other regions that little needs be

said here. Ammophila characterizes the crest, associating with heath forms as the plain slopes toward the west. Just north of Rehoboth is a good example of this condition. Here scant Ammophila growth is accompanied by *Lespedeza procumbens*, *Sarothra gentianoides* (*Hypericum nudicaule*), *Lespedeza capitata*, *Helianthemum canadense*, and *Pinus rigida* just over the crest; while four clumps of *Panicum virgatum* stand out on the windward side among the scant vegetation creeping up from the Hudsonia complex.

3. HEATH.—Although small portions of heath occur in many places on the lee side of the first series of dunes, the heath proper must be considered as starting from the second series and extending back to the forest. Its chief characteristic appears to be its large number of species of varied distribution, with very few that stand out as character forms, even the most common plants not being characteristic of all parts of the heath. Just south of Rehoboth occurs the most typical piece of this formation (*fig. 9*), being less interrupted by roads, cultivated fields, etc., than elsewhere, consequently most of the forms mentioned were collected in this region. It is a wilderness of *Baptisia tinctoria* and blackberries (*Rubus villosus*, *R. cuneifolius*, *R. canadensis*), with occasionally almost meadow-like growths of Ammophila. In clumps or singly rise cedars (*Juniperus virginiana*), persimmons (*Diospyros virginiana*), pines (*Pinus virginiana*, *P. rigida*), oaks (*Quercus digitata*), *Prunus maritima*, *P. pennsylvanica*, *Myrica cerifera*, *Rhus copallina*, and *Helianthemum canadense*, with an occasional *Sassafras sassafras* (*S. officinale*). A bush or two of *Rosa humilis* appeared at two points, and holly (*Ilex opaca*) at only one. Among the herbaceous dicotyledons from rare to frequent were observed *Solidago juncea*, *S. canadensis*, *Eupatorium album*, *E. hyssopifolium*, *Erigeron ramosus*, *Leptilon canadense*, *Aster ericoides*, *Gnaphalium obtusifolium* (*G. polycephalum*), *Achillea Millefolium*, *Lactuca canadensis*, *Hieracium Gronovii*, *Ascyrum hypericoides*, *Sarothra gentianoides*, *Asclepias tuberosa*, *Linaria canadensis*, *Trichostema dichotomum*, *Meibomia arenicola* (*Desmodium lineatum*), *M. obtusa* (*D. ciliare*), *Rumex* sp., and in

some places *Hudsonia tomentosa* forming small, almost pure formations. Of the monocotyledons, next in importance to Ammophila comes *Andropogon virginicus*, becoming more abundant as Ammophila decreases toward the west. With it are also associated in different places (besides various dicotyledons) *Agrostis alba*, *A. hyemalis* (*A. scabra*), *Eragrostis pectinacea*, *Panicum sphaerocarpon*, *P. viscidum* (*P. scoparium*), and *Poa compressa*; *Paspalum setaceum* occurring rarely. In many places there appeared a carpet of lichens and mosses, the most prominent of which were "reindeer moss" (*Cladonia rangiferina*) and *Ceratodon purpurea*, while Geasters occurred frequently in such situations. Lianas were almost entirely absent, *Parthenocissus quinquefolia* (*Ampelopsis quinquefolia*) being found at only three points, *Vitis aestivalis* on one dune summit, while *Smilax rotundifolia* occurred only in the pine swamp described.

FIG. 9.—Heath south of Rehoboth, looking nearly due west.

At one point south of Rehoboth, a single dune rising from a bare space has developed upon its summit a heath flora, com-

posed of plants which occur elsewhere only rarely or not at all. Among a thicket of blackberries, indigo, and cedars was found the only plant of *Crataegus coccinea* (*C. pruinosa* Wendl.) appearing in the whole region. *Vitis aestivalis* and *Festuca octoflora* (*F. tenella*) were also found here only. Besides these, there appeared the usual heath forms: Andropogon, Lechea, *Meibomia obtusa*, *Lespedeza capitata*, Hudsonia, *Panicum sphaerocarpon*, with *Solidago sempervirens*, *Galium pilosum*, and *Poa pratensis*. By roadsides and near dwellings were found such plants as *Plantago lanceolata*, *Poa pratensis*, *Daucus Carota*, *Achillea Millefolium*, *Lepidium virginicum*, *Chrysanthemum Leucanthemum*, etc., while one clump of *Opuntia* sp. occurred back of a cottage at the extreme end of the village.

B. Wooded region.—1. THICKET FORMATION.—This formation was merely glanced at in one situation, therefore no general idea can be formed of its character. At this one point were found *Aronia arbutifolia* (*Pyrus arbutifolia*), *Malus malus* (*Pyrus malus*) from cultivation, *Seriocarpus astroides* (*S. conyzoides*), *Ilex glabra*, *I. opaca*, *Vaccinium corymbosum*, *V. arboreum*, *Juniperus virginiana*, and *Pinus rigida*. With these forms occur many heath species, for this formation grades on the one hand into the heath and on the other into the pine forest.

2. FOREST FORMATION.—About a mile west of the village the oak woods appear as a belt back of the pine region. Here appears *Quercus digitata*, which gives place to *Q. alba*, *Q. coccinea*, and *Q. nigra*, with an occasional *Hicoria ovata* (*Carya ovata*). In the oak woods a canal has been started towards Rehoboth bay, but it is now abandoned, forming a deep cut partly filled with water and supporting a swamp flora. The excavation has broken up the fixed condition of the soil, and just west of the canal, possibly composed of the excavated sand, rises a fair-sized dune (*fig. 10*). At this distance from the coast the northeast and southwest winds seem to be about equal, and the dune is "going both ways," a process resulting in a flattening of the crest. It is of rather loose sand, with very little vegetation; grasses and occasionally a composite or sedge were all that gave it character.

Back in the country, pine and oak belts alternate for some distance, but no attempt to study this region was made.

V. CONCLUSIONS.

Dr. Harshberger[8] and Mr. Kearney[9, 10] have given sufficiently extended discussions of the geographical affinities of the floras of New Jersey, Ocracoke, and Virginia, to render any additional

FIG. 10.—Dune west of Rehoboth.

remarks unnecessary, only a few words being required to place these observations in line. The conditions on the Delaware strand are in general similar to the conditions on the whole Atlantic coast, the Gulf,[11, 12] and Lake Michigan shores. The beach is characterized by a succulent zone, in which Cakile and

[8] *Loc. cit.*, 658. [9] The plant covering of Ocracoke island, p. 312.

[10] Report on a botanical survey of the Dismal Swamp region, p. 458. Contrib. U. S. Nat. Herb. 5: 321–585. 1901.

[11] LLOYD, F. E. and TRACY, S. M., The insular flora of Mississippi and Louisiana. Bull. Torr. Bot. Club **28**: 61–101. *pls. 8–11.* 1901.

[12] WEBBER, H. J., Notes on the strand flora of Florida. Science, N. S. **8**: 658. 1898.

Salsola almost invariably occur, although their accompanying forms, Xanthium and Atriplex, are not so widely distributed. On the dunes the character plant, Ammophila, is of northern distribution, and is not found south of Chesapeake bay, but is abundant on the Michigan coast. Of its associates, *Euphorbia polygonifolia*, *Leptilon canadense*, and *Cenchrus tribuloides* are widely distributed, *Panicum amarum* is absent from the lake flora, and *Oenothera humifusa* extends along the Atlantic coast only to New Jersey.

Back of the first line of dunes, the combination of low dunes, swamps, and meadows offers a wide choice of habitat for plants, and we find many plants of wide range. The dune-holder *Hudsonia tomentosa* is a plant of northern distribution, Maryland being its southern limit, but it has a western range. Associated with Hudsonia, such forms as *Myrica cerifera* and *Baccharis halmifolia* are distributed along the Atlantic coast, but neither is found on Lake Michigan. Many grasses, sedges, and legumes are widely spread and need not be taken into consideration. *Strophostyles helvola*, very characteristic in Delaware, is mentioned only in the reports from New Jersey and Mississippi. *Spartina patens* shows a preference for salt conditions, appearing all along the sea and gulf strand, but not forming a part of the lake flora. Among the plants characteristic of the heath we find some widely distributed grasses and composites, although *Juniperus virginiana* stands out preeminently the most widely spread. *Quercus digitata* and *Diospyros virginiana* extend from Rhode Island and New York to the gulf; *Rhus copallina* is mentioned only in the New Jersey and Virginia floras; while the widely spread *Rhus radicans* (*R. Toxicodendron*) was found at Rehoboth in only one situation in the woods. Of the pines, *Pinus Taeda*, reaching (according to Britton and Brown) its northern limit in Delaware, was not found, although it is reported at Cape May, the peculiar conditions there obtaining accounting for its presence.[13] *Pinus rigida* and *P. virginiana*, however, extend north and south of this region.

[13] HARSHBERGER, 632.

A surprising lack of lianas was observed in the Delaware region, Parthenocissus occurring occasionally, and *Vitis aestivalis* and *Smilax rotundifolia* appearing in one situation, while "trumpet creeper" was collected in the surrounding country. This scarcity of climbers is in striking contrast to the condition described for other strand regions.

The pine swamp flora (Osmunda, Dryopteris, Oxycoccus, etc.) is composed of the usual undrained swamp forms, but no Sphagnum was found, and apparently the same is true of New Jersey, although one or two species are reported for Virginia.[14]

The similarity of strand conditions is therefore shown by the similarity of floras, for regardless of a wide difference in temperature there is a striking resemblance between the lists of forms found in New Jersey and Delaware and those reported for Mississippi, Louisiana, and Florida, while in spite of the fresh water condition on Lake Michigan the occurrence there of many genera and species which also inhabit the ocean strand bears evidence of common factors in the environment. These seem to be the excessive light and heat and strong wind-action of the sandy regions, the last being probably the most important element. In addition, the power of a large body of water in equalizing temperature explains in part the presence of many forms on the New Jersey, Delaware, and the Gulf coasts.

I wish here to express my thanks to Dr. C. F. Millspaugh of the Field Columbian Museum, Mrs. Agnes Chase of Chicago, Dr. J. N. Rose of the National Museum, and Dr. J. W. Harshberger of the University of Pennsylvania, for their kind assistance in identification; and I wish also to acknowledge my indebtedness to Dr. H. C. Cowles and Professor John M. Coulter for valuable criticism and suggestions.

THE UNIVERSITY OF CHICAGO.

[14] KEARNEY, Dismal Swamp 428

BRIEFER ARTICLES.

A NEW WESTERN CAMASSIA.

In 1880 Mr. William N. Suksdorf collected in Falcon valley, Washington, specimens of Camassia, which were sent to the Gray Herbarium for identification. One of these specimens was correctly referred by the late Sereno Watson to *Camassia esculenta* Lindl.; the other, an incomplete specimen, and a duplicate collected in 1883, were referred to *C. Leichtlinii* Watson. Since that time the same collector has carefully watched the growth of these plants in the field, and has even brought several species of the genus into garden cultivation for the purpose of ascertaining their true systematic position and relationship. Full notes and additional complete specimens have been forwarded the writer by Mr. Suksdorf, together affording the satisfactory separation of the plant from the species with which it has been hitherto confused, as well as from all other described species of the genus. It is fitting that this new Camassia bear Mr. Suksdorf's name, and the author takes great pleasure in dedicating it to him. A description is herewith appended:

Camassia Suksdorfii Greenman, n. sp.— Bulbs ovate, 1 to 2^{cm} in diameter: leaves narrowly lorate, 3^{dm} or less long, 0.5 to 2^{cm} broad: scape 3 to 7^{dm} high, few-flowered: bracts lance-attenuate, membranous, mostly shorter than the elongated 1–3.5^{cm} long arcuate-ascending pedicels: flowers regular, blue or in the dried state somewhat violet, fully 5^{cm} in diameter when completely expanded; perianth segments lanceolate, 3 to 3.5^{cm} long, about 8^{mm} broad, mostly 5-nerved, in the later stages closing over the ovary and becoming somewhat spirally twisted: cells of the ovary about 12-ovuled: capsule 1.5 to 3.5^{cm} long, 10 to 12^{mm} in diameter, obtusely angled: seeds ovate, 3 to 4^{mm} long.— Washington, in wet meadows, Falcon valley, *Suksdorf*, no. 251, June–July 1883, and July 1880, *Suksdorf*, no. 509; near Bingen, altitude 600^{m}, 21 May 1900, *Suksdorf*, no. 2663. A white-flowered form of this species was collected in a wet meadow in W. Klickitat county, Washington, altitude about 600^{m}, 19 May 1891, *Suksdorf*, no. 2023.

The species here proposed is distinguished from *Camassia esculenta*

Lindl. by the larger flowers, longer pedicels, which usually exceed the subtending bract, and by the larger fruit and seed. In the mature specimens the capsules are erect and disposed on arcuate-ascending pedicels, so that the fruiting raceme is 4 to 5^{cm} in diameter instead of 2 to 3^{cm} as in *C. esculenta*. From *C. Leichtlinii* Watson, to which Suksdorf's no. 509 was referred, *C. Suksdorfii* differs in the color of the flowers, the less sharply triangular, thinner, and less conspicuously nerved capsule. The seeds, moreover, in *C. Suksdorfii* are longer and have a more bluish luster than in *C. Leichtlinii*.—J. M. GREENMAN, *Gray Herbarium*.

CURRENT LITERATURE.

BOOK REVIEWS.

Vegetation der Erde.

THE VEGETATION of the Illyrian countries forms the topic of the fourth volume [1] of this splendid series of monographs edited by Engler and Drude. The area covered by the work ignores political and to some extent phytogeographic boundaries, embracing the field which Dr. Beck has for many years made peculiarly his own. In a general way the region under discussion corresponds to the ancient Roman province of Illyria, and includes Servia, Montenegro, and the western portion of European Turkey, as well as the southern part of the Austro-Hungarian empire. The Slavic tongues dominate in most of the Illyrian regions, and many of the best botanical workers have been natives. Among those prominent in phytogeographic study have been Visiani, Sendtner, Vandas, Baldacci, Pancić and Adamović. Since 1886 Beck has published many important papers which have amply fitted him for this monograph. The bibliography includes about 800 titles.

After a brief treatment of the geography and climatology, the formations are described in detail. Among the most interesting of the formations are the well-known Mediterranean evergreen forests and thickets, in which forms with broad leathery leaves (Schimper's sclerophylls) dominate. The peculiar evergreen thicket, known as the maqui or macchie, is the most typical of Mediterranean formations and does not depart far from the sea; among the character plants are the arbutus, laurel, myrtle, olive, evergreen oaks, Spartium, juniper. This unique vegetation is believed to be due to the unique climate, the winter being mild while the summer is hot and dry. In some places near the sea *Pinus halepensis* is a leading plant, preceding the maqui rather than following it. Woods are also composed of *Pinus nigra*, laurel, and various oaks. Vast areas are covered by rocky heaths, especially in limestone regions; under favorable conditions near the sea a rock heath is an early stage of the maqui.

In the interior the forests are dominated for the most part by deciduous

[1] BECK VON MANNAGETTA, DR. GÜNTHER RITTER, Die Vegetationsverhältnisse der illyrischen Länder begreifend Südkroatien, die Quarnero-Inseln, Dalmatien, Bosnien und die Hercegovina, Montenegro, Nordalbanien, den Sandzak Novipazar und Serbien. 8vo, pp. xv + 534, with 6 full page plates, 18 text figures, and 2 maps. Leipzig: Wilhelm Engelmann, 1901. Subscriber's price *M* 20, bound *M* 21.50; separate price *M* 30 bound *M* 31.50.

oaks. *Pinus nigra* appears early in rock formations inland; with this exception there is little in common between the Mediterranean and inland forests. There are great areas of rocky heath inland having the physiognomy but not the floristic features of the heaths near the sea. The inland heath, too, is potentially a forest, while the coastal heath is an expression of the Adriatic climate.

A third section deals with the mountains and many interesting features are here described. There is a decided dominance of xerophytic associations, alpine meadows and similar formations being rare. Magnificent forests of beech, fir, and spruce characterize the lower portions of the mountains, just above the oaks. This forest type is not found on the seaward side of the mountains because of the severe climate, which permits only xerophytic trees like *Pinus nigra* to prosper. The beech approaches the lowlands more than do the spruce and fir, while the latter are more characteristic of the higher mountain districts. Various pines dominate in xerophytic areas. The subalpine thicket is composed of pine, juniper, and various other shrubs which form a typical "krummholz." The alpine plants embrace a large number of endemic species, but there are also many widespread forms.

The work concludes with some chapters on the floristic subdivision, history, and relationship of the Illyrian countries. Though the subdivision is purely floristic, rainfall is regarded as the chief distributional factor. The book is well up to the high standard previously set by Willkomm, Pax, and Radde. It is also of peculiar importance since it is the only available work which sums up for general use the broad facts of plant distribution in southeastern Europe.—H. C. COWLES.

MINOR NOTICES.

KENNETH K. MACKENZIE, assisted by B. F. Bush and others, has published a *Manual of the flora of Jackson county, Missouri*.[2] It brings together the records of several local floras, beginning with the *Flora of Jackson county* by Mr. Bush in 1882. So far as the reviewer knows, this is the first manual with full descriptions and keys devoted to a single county published in the United States. The advantages of such a manual for local use are very evident, and the students of botany in Jackson county are specially favored. The book is exceptionally well printed, and with its keys, glossary, and indexes is a very complete manual. The summary shows that 1141 species and 51 varieties are included.—J. M. C.

A NEW disease of cultivated bananas near Alexandria, Egypt, has been noted for three years.[3] It is characterized by a sudden check of growth, the leaf-points and central leaf blacken and die, putrefaction sets in and proceeds

[2] 8vo, pp. xix + 242. Kansas City, Mo. 1902.

[3] FAWCETT, WILLIAM, A banana disease. Bull. Bot. Depart. Jamaica IX, 100-105.

downward in the latter, and the stem bears many small, crippled leaves. Nematodes were found to be the cause of the trouble. Recently the same disease has again appeared near Alexandria. Microscopic examinations showed that the nematodes were more abundant in the secondary roots than in the main ones. The secondary roots are destroyed, the food supply is thus cut off and the growth is checked in consequence. The matter is complicated by the presence of other species of nematodes. "Trap-crops" are suggested for the removal of most of the nematodes. This it is argued will remove so many that they will not be especially injurious. No other definite remedy is given.—P. SPAULDING.

NOTES FOR STUDENTS.

P. J. O'GARA,[4] of the University of Nebraska, has conducted experiments which indicate that *Sphaeropsis rhoina* of the sumac and *S. malorum* of the apple are the same fungus. At least, the former will cause black rot in the fruit of the apple, and will also produce the typical "canker" on the branches just as readily as the latter.—J. M. C.

MRS. E. G. BRITTON and Miss A. Taylor[5] have published an account of the morphology and anatomy of *Vittaria lineata*. The prothallium is irregularly branched and consists of a single plate of cells. It has remarkable powers of vegetative propagation and produces gemmae very similar to those described by Goebel for *V. elongata*. The antheridia are very numerous, and are produced either upon the ventral surface of the prothallium or upon the gemmae, and rarely upon the same prothallium as the archegonia. The development of the antheridium is of the usual polypod type, with funnelform wall and cap cell, and twelve or twenty-four sperms are produced. The long stalk of the sporangium seems to be formed chiefly by a single row of three or more elongated cells, longitudinal divisions occurring next to the spore-case. The interesting observation is made that the small stalk-cells at the base of the spore-case become very much inflated, and when the case opens they tilt it back. Long-stalked, branching, and multicellular paraphyses occur among the sporangia, the terminal cells being elongated, curved, and enlarged at apex.—J. M. C.

ITEMS OF TAXONOMIC INTEREST are as follows: SPENCER LEM. MOORE (Jour. Bot. **40**: 305. *pl. 441*. 1902) has described a new African genus (*Amphoranthus*) of Caesalpineae from Damaraland.—E. L. GREENE (Pittonia 5: 1–56. 1902) has published 6 new species of Acer, 22 new species of Microseris, 14 new species of Phacelia, 7 new segregates of *Viola canadensis*, 8 new acaulescent violets, a revision of Romanzoffia (10 species, 8 of which are

[4] Science **15**: 434–435. 1902.

[5] The life history of *Vittaria lineata*. Memoirs Torr. Bot. Club **8**: 185–211. *pls. 23–31*. 1902.

new), a revision of Capnorea (14 species, 8 of which are new), 5 new species of Cryptanthe, and 3 new species of Compositae (Helenium, Thelesperma, Vernonia).—C. DECANDOLLE (Urban's *Symbolae Antillanae* 3²: 159–274. 1902) in his monograph of West Indian Piperaceae recognizes 70 species in Piper (21 new), 3 in Verhuellia, 79 in Peperomia (4 new), and excludes *Symbryon* Griseb.—JANET PERKINS (Engler's Bot. Jahrb. **31**: 481–494. 1902) has completed her study of Styracaceae and has revised the genus Lisianthus (Gentianaceae).—ALICE EASTWOOD (Bull. Torr. Bot. Club **29**: 523–525. 1902) has described new western species of Castilleia, Lappula, Corydalis, and Campanula (2).—H. D. DEBOISSIEU (Bull. Herb. Boiss. II. **2**: 803. 1902) has described a new genus (*Melanosciadum*) of Umbelliferae from China, belonging to the Smyrnieae.—J. M. C.

PROFESSOR STRASBURGER, in his first paper[6] on double fertilization, insisted that in fertilization two processes should be recognized: the stimulation to development and the mingling of ancestral qualities, the latter process being the essential one, and the stimulation to development only providing the conditions which make it possible to attain the advantages which result from a mingling of ancestral plasma masses. In a recent paper[7] he defines very clearly his own views and makes critical references to recent work. Fluctuating variations do not furnish a starting point for the formation of new species. It is the principal function of fertilization, through the mingling of ancestral plasma masses, to keep the species characters constant. This view agrees with that of Richard Hertwig and approaches that of Solms-Laubach in so far as the latter regards "so-called fertilization," or the fusion of hereditary masses, as an essential element in fertilization; but Solms-Laubach regards the stimulation to development as an equally important attribute of fertilization. Strasburger, however, defines the "so-called fertilization" definitely as the union of the two hereditary plasma masses and believes that it was to insure this essentially "generative fertilization" that in the course of phylogenetic development the inability of the sexual cells to develop indepeudently without fusion became more and more marked. The term "generative fertilization" is used to designate a union of ancestral plasmas, in contrast with "vegetative fertilization," which is merely a stimulus to development. Were it not for the fact that the two processes occur simultaneously, the distinction would have been recognized long ago. The term "fertilization" has often been loosely used in cases like many nuclear fusions in fungi, where there is no union of hereditary masses, but only a stimulus to development. While Strasburger would be willing to admit that the stimulus to development might be due to chemical or physical influences, he insists that "generative fertili-

[6] STRASBURGER, ED., Einige Bemerkungen zur Frage nach der doppelten Befruchtung bei den Angiospermen. Bot. Zeit. **58**: 293–316. 1900.

[7] STRASBURGER, ED., Ueber Befruchtung. Bot. Zeit. **59**: 1–8. 1901.

zation" is not a purely chemical process. Winkler suggests that bastards might be produced by chemical fertilization. Strasburger regards this as impossible and believes that the essence of fertilization lies in the union of organized elements. The view that the epigenesis of form is only an expression of the epigenesis of chemical power might, perhaps, appeal more to the physiologist than to the morphologist who has studied more deeply the developmental history of organisms. No doubt morphologists busied themselves too long with a one-sided mechanical view of ontogeny. If the chemical theory does not in the same way go beyond the mark, the two views united should be useful in extending our knowledge.—C. J. CHAMBERLAIN.

IN a rather extended paper Van Tieghem[8] indicates his ideas of taxonomy as developed in the light particularly of researches upon ovular anatomy and morphology. For some time systematists have been familiar with the revolutionary attitude of the dean of French botanists, and his long successions of new families of plants have been duly noted in the bibliographies, but have not produced any general modification, either in Germany or America, of the current taxonomic sequences. Indeed, it would be a somewhat serious matter if it became necessary to rearrange herbaria upon the Van Tieghem system, since it is a complete *bouleversement* of the Engler-Prantl order, which has recently pretty generally superseded the old Benthamian arrangement of the families.

The object of M. Van Tieghem is apparently to develop a new classification founded upon the methods of reproduction in plants; how successful he has been must be left to the consensus of botanists to determine. The reviewer, after a careful examination, finds himself unable to follow Van Tieghem either in the general plan of his system or in the detail of its elaboration. To go over the points one by one would be impossible in a brief review, and I shall select but a couple of examples for criticism, believing that they will illustrate the system as a whole.

Van Tieghem begins by dividing the plant kingdom into two subkingdoms which he calls *Diodeés* or Prothalleés and *Adiodeés* or Aprothalleés. One finds that in the Adiodeés, which is the lower group, types from Protococcus to Polytrichum are included. Here too are such forms as Vaucheria and Fucus. In the Diodeés are the ferns and flowering plants. The distinction between the two subkingdoms according to Van Tieghem is the production of the eggs directly upon the "plant-body"—*naissance directement sur le corps adulte*—in the Adiodeés, and upon a special rudimentary body—the prothallium—in the Diodeés. Van Tieghem characterizes the former as "direct" formation of the egg and the latter as "indirect." Such a classification ignores the homologies established by Hofmeister and accepted

[8] VAN TIEGHEM, PH., L'oeuf des plantes, considéré comme base de leur classification. Ann. Sci. Nat. Bot. VIII. 14: 213–390. 1901.

universally since his time. It is at variance with modern ideas of alternation of generations and its significance. It fails to preserve the unity of the archegoniate series, but breaks it in two in the middle, separating closely related forms and throwing Anthoceros into one subkingdom and Phylloglossum into another. This is distinctly reactionary and opposed to the great current of embryological research from Von Mohl to Bower. The further subdivision by Van Tieghem of his Diodeés into *Exoprothalleés* and *Endoprothalleés* is equally artificial and objectionable.

Turning now to a matter of detail. Van Tieghem places at the bottom of his class Homodiodeés the *Inovuleés*, characterized by the absence of ovules. That brings the Loranthaceae practically to the bottom of the dicotyledons, a most improbable position for a group of metaspermic parasites. Reduction in such plants might be expected in connection with the high ecological specialization, but rudimentary structure would be altogether astonishing in the family to which the mistletoe belongs. It is rather in the aquatic medium that one would expect the primitive dicotyledons, and, indeed, in such plants as Nelumbo, investigated by Lyon, and Ceratophyllum, studied recently by Strasburger, the transition from the monocotyledonous to the dicotyledonous habit can be seen. No system that confuses reduced structures such as the placentation and ovule of the Loranthaceae with genuine rudimentary and simple structures can command wide adherence.

From top to bottom, both in the general and in the special portions, the Van Tieghem classification seems to be an inversion of the truth. Nevertheless, it is a distinctly ingenious and stimulating piece of work, and has already more than justified the labor spent upon it by its venerable and distinguished author, in the light it has thrown upon some of the smaller and more obscure groups of dicotyledonous plants. That it will be generally accepted is improbable, and it seems doubtful whether it will gain much currency even in France. The students of systematic botany, however, will be fully repaid by reading it, for it is both brilliant and interesting.—CONWAY MACMILLAN.

NEARLY FIFTY YEARS AGO there was described a species of Dischidia with remarkable double pitchers. Pearson[9] now makes an examination of the phenomenon. He finds double pitchers in four species of the genus: *D. complex* Griffith, Malacca; *D. pectenoides* Pearson, n. sp., Philippines; *Dischidia* sp., Borneo; *Dischidia* sp., Borneo; the last two are undescribed, and in very imperfect condition. The pitchers in these species, as in the other pitcher-producing species of the genus, of which by no means all show this characteristic, are morphologically leaves, the inner surface of the pitcher being homologous with the under surface of the foliage leaf. The origin of

[9] PEARSON, H. H. W. On some species of Dischidia with double pitchers. Jour. Linn. Soc. **35**: 375–390. *pl. 9.* 1902.

the simple type of pitcher seems to result from an early arrest of apical growth and a rapid growth of the central portion of the morphologically upper surface with a consequent bulging out. In the double pitchers, the structure of which is described in detail, the inner pitcher may be supposed to have been formed first, since in the development of the pitchers of *D. Rafflesiana* apical and basal growth in the leaf ceases at an early stage, and the pitcher has assumed a definite form, so that in species with the double pitchers a resumption of apical growth, with the accompanying involution which gives rise to the inner pitcher, can hardly be supposed. As to the function of the pitchers, conclusions based on herbarium material must necessarily be unsatisfactory. Fairly complete investigations have quite conclusively shown that the pitchers of *D. Rafflesiana* are to be regarded as living "flowerpots," containing, as they usually do, water and soil and being supplied with a copious root system. In the four species under consideration, all of which are epiphytes, and clearly xerophytic in structure, the author was able to examine the contents of nine pitchers, all of which contained roots, and in all cases more or less soil in the outer but none in the inner pitchers. It seems, as Groom believes to be the case in *D. Rafflesiana*, that the greater the amount of soil the greater the development of roots in the outer pitcher. That ants bring the soil into the pitchers of these species the author of the paper considers certain, the ants making their nests in the pitchers. To what extent the plant depends upon the food material contained in these organs is unknown, but the indications are that they are of no inconsiderable importance. As to the benefit derived by the ants from this symbiotic relation, the pitchers are convenient shelters and nesting places, for which the four species may be assumed to be better adapted than *D. Rafflesiana*, on account of the narrower entrances and more commodious forms. As to the function of the inner pitcher, they may possibly serve as a place of refuge for the ants in case of danger from drowning. There is some indication, in *D. pectenoides* at least, of a possible function as a feeding ground, the food material being a sweetish substance, evidently a decomposition product. Examination of the inner wall of the outer pitcher reveals the presence of a dense weft of superficial mycelium, the explanation of the presence of which was impossible. A similarity to forms described by Muller in the "fungus gardens" of some South American ants was noticed. Dischidia, then, shows a series of modified leaves more remarkable perhaps than any other known genus, the highest specialization of which is found in the four species here described, where the adaptation to the residence of ant colonies as well as the economy of water seems to have reached its highest point.—J. ARTHUR HARRIS.

EDGAR W. OLIVE [10] has published a detailed account of the Acrasieae,

[10] Monograph of the Acrasieae. Proc. Boston Soc. Nat. Hist. **30**: 451–513. *pls. 5–8.* 1902.

whose problematical relationship to the Myxomycetes has been the subject of considerable discussion. The two groups of Acrasieae (Guttulinaceae and Dictyosteliaceae) agree in that the vegetative individuals assume the form of amoeboid cells which never pass through a swarm cell condition, and in that the individuals during the fructifying period unite to form colonies (pseudoplasmodia); but they differ widely in the general character and structure of their fructifications, the Guttulinaceae showing little or no differentiation, and the Dictyosteliaceae considerable differentiation both in structure and function. In certain forms two types of division were observed; one in the young individuals shortly after germination, occupying a number of hours and accompanied by prolonged nuclear changes that resemble karyokinetic division; the other during the subsequent active amoeboid condition, resembling direct division and taking place usually within a few minutes. In a discussion of the sytematic relations of the Acrasieae, the author states that there can be no question as to the common origin of the Myxomycetes and the Acrasieae, but that when the two groups are carefully compared it appears unlikely that the former have been derived directly from the latter, since the amoeboid stage is in reality the only feature strictly comparable. The families and genera recognized are as follows: Sappiniaceae: *Sappinia* Dangeard (1 sp.); Guttulinaceae: *Guttulinopsis* Olive (3 spp.), *Guttulina* Cienkowsky (4 spp.); Dictyosteliaceae: *Acrasis* Van Tieghem (1 sp.), *Dictyostelium* Brefeld (7 spp.), *Polysphondylium* Brefeld (3 spp.), *Coenonia* Van Tieghem (1 sp.). —J. M. C.

ONE OF DR. ENGLER'S latest conceptions, which is already beginning to find concrete realization, is a vast botanical garden, which shall display the characteristic plant formations of the world. The underlying idea in Dr. Engler's scheme is floristic rather than ecological, although typical edaphic plant societies find representation. He had already outlined in detail his plan for an alpine garden — this has received very favorable mention, and may be referred to somewhat fully in these pages at another time. In a pamphlet[11] of nearly a hundred pages Dr. Engler gives a plan of the garden and states his ideas in full as to the floristic subdivision of North America north of Mexico. The four chief divisions are *Arctic*, *Subarctic*, *Atlantic*, and *Pacific*. The Arctic division is like that of Europe and is not treated. Subarctic North America is subdivided into eastern, central, and western districts (Bezirke). Atlantic North America is subdivided into four provinces; lake, Mississippi and Alleghany deciduous forest, south Atlantic evergreen, and prairie. Pacific

[11] ENGLER, DR. ADOLF, Die pflanzengeographische Gliederung Nordamerikas erläutert an der nordamerikanischen Anlage des neuen Königlichen botanischen Gartens zu Dahlem-Steglitz bei Berlin. Separate reprint from Notizblatt Königl. Bot. Gart., Appendix IX. 8vo. pp. iv + 94, with plan and distribution map. Leipzig: Wilhelm Englemann. 1902. *M* 2.40.

North America is subdivided into three provinces: Pacific conifer, Rocky mountain, southwestern arid or semi-arid. All of these areas are further subdivided and characteristic formations and species are given in some detail. Occasionally there are errors to be found in the alignment of species, as might be expected in a paper which is largely a compilation from the works of Sargent, Brendel, Mohr, Kurtz, Pound and Clements, and others. However, the broad outlines of the work are remarkably true to the facts. It is particularly interesting to see Atlantic and Pacific America separated into primary divisions, recognizing that the great cleavage lines in the United States run north and south. Ecologists have always known that the plant formations of this country had such an orientation, but many students of floristics during the last decade have attempted to make their great cleavage lines run east and west. We may hardly regard the question as settled, but rather opened up for further study. The details in Engler's paper are remarkably true in most instances; indeed one is obliged to confess that it is the best floristic presentation of the vegetation of this country which has yet appeared. Though designed to indicate the plan of a botanical garden in Germany, it is nevertheless so important a contribution to American phytogeography as to be a necessary work of reference.— H. C. COWLES.

R. H. YAPP[12] has recently treated of the anatomy, biology, and systematic position of *Polyodium* (*Lecanopteris*) *carnosum* and *Polypodium sinuosum*. As to systematic position, he concludes that while that of *P. carnosum* has been a debatable one, both of the forms should be regarded as closely allied species, both from external features and internal structure. Both are Malayan epiphytes. *P. carnosum* grows only in the higher branches of trees and usually on fairly high mountains, where it forms thick encrusting masses often several feet in length; while *P. sinuosum*, whose creeping rhizomes not forming such thick masses as those of *P. carnosum* are frequently seen quite near the ground, and usually on the trunk itself or on the main branches of its host, is often found almost at sea level. The distribution of *P. sinuosum* is more extended than that of *P. carnosum*. The thick fleshy rhizomes of these epiphytes are tunneled by a system of galleries similar to those of *Myrmecodia* and *Hydnophytum*, and like them invariably inhabited by ants. The origin of the galleries is similar in the two species. About 1–2^{mm} from the growing point and after the differentiation of procambium and protoderm, the parenchymatous cells in certain definite areas undergo a more rapid increase in size than those of the remaining ground tissue, the difference in size becoming more marked farther back from the apex. These zones of tissue, whose cells have increased so remarkably in size with little or no division, are sur-

[12] Two Malayan myrmecophilous ferns, *Polypodium* (*Lecanopteris*) *carnosum* (Blume), and *Polypodium sinuosum* Wall. Ann. Botany **16**: 185–231. *pls. 10–12.* 1902.

rounded by a zone several layers deep of relatively small brown cells, which has been developed by radial and longitudinal division during the increase in size of the cells of the included tissue. At a distance of 2^{cm} from the apex, the large cells, which have been filled chiefly with water, the walls having merely a film of protoplasm, break down, giving rise to the ant galleries, which are thus of lysigenous origin. The arrangement of the galleries is in both cases regular, although not exactly the same, a main ventral longitudinal gallery giving off two lateral series of galleries to the branches and two vertical series leading to the leaf-cushions, branching soon after leaving the ventral gallery to form two longitudinal series of dorsal chambers. Communication with the external air is secured by short passages excavated in the soft tissue of the younger parts of the stem by the ants themselves. While the function of the galleries is still somewhat obscure, the large-celled tissue seems to have been developed as a special water-reservoir, but its early disintegration may indicate an important function in the galleries, as aeration or to a slight extent absorption of water. There is no evidence that the galleries are an adaptation on behalf of the ants. In *P. carnosum* the marginal lobes upon which the sori are borne are reflexed at maturity so that they are turned upward, this being possibly an adaptation to secure the distribution of the spores during a strong wind, which would be most favorable for a high growing epiphyte.—J. ARTHUR HARRIS.

NEWS.

PROFESSORS HUGO DE VRIES and Julius Wiesner have been made members of the Accademia dei Lincei.

DR. N. L. BRITTON was in England during August and September completing his investigations of American Carices and Crassulaceae.

J. B. DANDENO, formerly instructor in botany at the St. Louis Normal School, has been appointed assistant in botany at the Michigan Agricultural College.

COULTER AND ROSE'S *Monograph of the North American Umbelliferae* has been reprinted by the Department of Agriculture, and was issued September 22, 1902.

AMONG THE FALL ANNOUNCEMENTS of Henry Holt & Company is *Plant Physiology* by George J. Pierce; and among those of D. C. Heath & Company is *An introduction to Botany* by W. C. Stevens.

THERE WAS AN ATTENDANCE of forty-four in botany at Woods Hole this summer, including the staff and investigators. Among the latter were Professor Duggar, Drs. Miyake and Overton, and Mr. George D. Fuller.

L. COCKAYNE, whose fine work on the vegetation of Chatham island, New Zealand, will soon be reviewed in this journal, has been granted a passage in the government steamer to the Antarctic islands. He plans to sail during December and will carry on ecological and floristic studies.

THE BOTANICAL SOCIETY OF AMERICA will hold its ninth annual meeting at Washington, D. C., December 29, 1902, to January 3, 1903, under the presidency of Dr. B. T. Galloway. The address of the past president, J. C. Arthur, and a program of scientific papers will be given at the sessions.

A BIOGRAPHICAL SKETCH of the late Marc Micheli, prepared by C. de Candolle, and accompanied by a portrait and bibliography, is published in *Archiv. Sci. Phys. et Nat. Geneva* of July, 1902. The bibliography includes thirty-four botanical titles. Micheli was born October 5, 1844, and died June 29, 1902.

THE BUREAU OF FORESTRY has established a dendro-chemical laboratory in cooperation with the Bureau of Chemistry, to study the chemistry of forest products. The laboratory is in charge of William H. Krug, and its first work has been a study of the chemical composition of the wood and bark of various oaks (chestnut, white, red, and black) and the western hemlock.

DR. ALEX. P. ANDERSON has resigned his position of curator of the

herbarium of Columbia University to become an expert to the syndicate now engaged in developing the new method of treating starchy grains, etc., recently discovered by Dr. Anderson in the laboratories of the New York Botanical Garden. Dr. Anderson is fitting up a laboratory for the continuance of his work at Minneapolis.—SCIENCE.

THE KIRBY LUMBER COMPANY, whose holdings are in southeastern Texas, has requested the Bureau of Forestry to prepare a working plan for its lands. The lumbering operations of this company extend over a tract of 1,250,000 acres of pine lands, which contain about 80 per cent. of all the long-leaf pine of Texas. This vast single body of virgin forest is uninterrupted except for the clearings around the villages and farms which it encloses.

THE EDITOR OF *Science* for the fifth year has published statistics in regard to the conferring of the degree of doctor of philosophy by American universities. It is of interest to botanists to know that during this period (1898–1902) fifty-three doctorates in botany have been conferred. The thirteen conferred during 1902 are as follows: W. A. Cannon (Columbia), G. P. Clinton (Harvard), J. W. T. Duval (Michigan), T. C. Frye (Chicago), C. S. Gager (Cornell), C. A. King (Harvard), A. A. Lawson (Chicago), B. E. Livingston (Chicago), Florence M. Lyon (Chicago), K. Miyake (Cornell), E. W. Olive (Harvard), R. H. Pond (Michigan), and C. E. Preston (Harvard).

DURING THE PAST SUMMER two ecological parties have been in the field from the University of Chicago. Dr. Henry C. Cowles, with a party of fourteen, has been studying the climatic and edaphic influences on the flora of Mt. Ktaadn, Maine. The results were very satisfactory, since a large number of plants and photographs were collected to supplement the field observations. Mr. Henry N. Whitford, with a party of eight, has been working in the vicinity of Flathead lake, Montana. Mr. Whitford plans to stay through a part of October, and is making a detailed map of the region. Messrs. C. D. Howe and L. H. Harvey, and Dr. B. E. Livingston have been doing individual work in Vermont, Maine, and Michigan.

WE LEARN FROM *Nature* that at the Belfast meeting of the British Association in September, Professor J. Reynolds Green, president of Section K (Botany), delivered an address dealing with the position of research in plant physiology, and its importance in agriculture. Papers were presented as follows: The morphology and past history of the Araucarieae, by A. C. Seward and Sybille Ford; Internodes and their relation to morphological problems, by Percy Groom; The dorsiventrality of the Podostomaceae, by J. C. Willis; The function of the nucleolus, and The nucleus of the Cyanophyceae, by Harold Wager; Sex in the genus Diospyros, and Foliar periodicity in Ceylon trees, by H. Wright; Fossil Nipa seeds from Belgium, by Messrs. Seward and Arber.